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STUDY OF
LIGHT WEIGHT METAL
FRAMING SYSTEM

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FRAMING SYSTEM

FOR

CANADA MORTGAGE

&

HOUSING CORPORATION

BY

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1. SYNOPSIS

The purpose of this study is to provide technical information, project experience, and to evaluate projected costs of Light Weight Metal Framing systems in residential construction.

Through this research, it should be possible to facilitate the use of these methods of construction in medium density residential projects. It is the author's experience that alternative building systems are required to supplement the existing methods of construction. With rising land costs, planning constraints and increased construction costs it is necessary to provide new building systems as part of the solution to the present housing crisis.

Light Weight Metal Framing also represents a potential "systems approach" to the building industry. It is felt that innovation in regard to the building industry starts with analysis of the construction site conditions. Innovation is achieved with alternative methods and materials used within the context of conventional skills, trades and experience.

The process for this study has been to survey, catalogue and present Light Weight Metal Framing systems which have been developed in North America. This has documented the technical information available, project experience, and has related this information to constraints in the building industry of central Canada.

It has formed an information base whereby this building system can be considered by other industry participants for future projects. The information and experience exists in scattered form throughout North America, and has not been assembled or related to the central Canadian market.

In order for Light Weight Metal Framing systems to be seriously considered by any architect, lender or builder for a future project, the information which is contained in this research project is required.

The type of construction, which is the subject of this report, has been described as "light weight metal framing" (L.M.F.), and has "load bearing steel stud construction". Both terms describe a construction method which utilizes steel members of twelve to twenty-two gage material, which is cold roll formed into structural sections which are used to construct buildings in a manner similar to traditional wood frame construction.

The buildings examined varied in configuration from 3 - 5 storey buildings with a theoretical upward limit to the building system of approximately 6 stories. This system relies upon dry wall assemblies to achieve fire and acoustic separations in ceilings and walls. Light Weight Metal Framing can be combined with other types of construction such as masonry bearing wall, wood stud partitions, and floor systems such as pre-cast concrete and open web steel joist and concrete. This building method has received some attention in the past few years in Canada as a method of constructing exterior walls, clad with traditional wood materials, aggregate panels, or brickwork.

Roof construction is achieved through truss configurations or with flat built up roof assemblies.

Floor assemblies vary in the examples studied from cold rolled joist sections with plywood subfloorings to precast configurations, but for the most part were comprised of cold rolled joist sections, with light gage metal pan concrete.

Wall assemblies were load bearing steel studs with a variety of cladding, depending on interior or exterior uses. In the examples studied in the U.S.A. simple insulation and vapour barrier techniques were used that would not be acceptable in Canada.

The examples studied may also be described as a simple intergration of Light Weight Metal Framing members into a primary structural system, where direct substitution was made with cold rolled sections for other traditional structural members.

This direct substitution does not, in the author's opinion, exploit all the potentials possible within the use of these materials in terms of pre-assembly of wall sections, such as factory installation of exterior claddings and wiring and interior finishes within wall section panels. Present methods of construction do not exploit to their full potential the intergration of packaged or pre-assembled mechanical systems. However, as with the history of many building system innovations, the direct substitution or conservative use of the system may in the long run prove to be the healthiest pattern on implementation. The risks involved to all concerned is substantially reduced and allows the gradual development of more sophisticated applications.

Cost projections contained in this study attempted to compare L.M.F. systems with load bearing masonry construction. In a theoretical project of 4651 m^2 (50,000 sq.ft.) the cost for a L.M.F. system in the Toronto region was approximately $71.48 per m^2 ($6.65 per sq. ft.). From examples studied and in conversation with industry users, this may vary

as much as 20% ±. In attempting direct comparisons with typical applications of a 3 x 6.1 m (10'x20') bay and a 6.4 x 8 m (21'x26') cost saving over masonry construction, the examples given showed a cost savings of approximately 12% with L.M.F. framing.

The cost projections and comparisons do not attempt to deal with regional differences in other areas of Canada or in projecting the effects that future economic, labour or construction conditions may have on the system. It can be conservatively assumed that due to the nature of the labour components in the system, sources of supply, and nature of fabrication, that in future periods high economic activity in the construction industry, cost savings may increase with the use of L.M.F. systems.

1(i) Summary

- examples displayed in this study vary from three to five stories;
- projects examined rely upon the simple substitution of light weight metal framing for other construction methods;
- detail assemblies vary from pure L.M.F. systems to combinations incorporating other traditional methods;
- sophisticated pre-assembled panels have not entered the market to any large degree at this time.

2. INTRODUCTION

2(i) Projects examined: The authors of this report have examined at first hand approximately eight projects constructed in the New York City area during the last three years. These consist of load bearing steel stud buildings from three to five stories in height and from approximately twenty units, to a project that will eventually comprise six hundred units.

Although these buildings ressemble in configuration many projects in Canada, the wall section and insulating requirements for that area are not as onerous as those in Ontario. Some code requirement differences also can be identified between the buildings constructed in the U.S. and that which would be required in Canada. However, they can be related to potential Canadian projects and serve as an excellent example for markets throughout southern Canada.

The impetus for this study is as a result of the author's experience with medium density housing projects in the Toronto area. The majority of new projects built both by the public sector and to a lesser degree by the private sector consist of what may be called medium density projects. These

consist of approximately 1 - 2 times the site coverage. At the present time they are usually constructed as a combination of six to eight storey buildings and townhouses. The authors believe that this is a result of the economic constraints placed upon developers by the building systems available in the southern Ontario building industry. The simple choices are to build with load bearing masonry or poured concrete construction to an economic height of about eight stories, and to divide family units or other units into row townhousing, constructed with combustible construction techniques.

The authors believe that L.M.F. offers an economical alternative which should allow construction of non-combustible intermediate size buildings that would enhance the choices available to architects, designers and developers for intermediate size projects.

Other direct advantages of L.M.F. are ones of non-combustible construction, low structural weights which would apply to areas with high earthquake loadings, envelope design of exterior wall assemblies for energy conservation, and shorter construction time periods.

In addition, as familiarity with this construction method develops, other benefits in terms of reduced costs and greater efficiencies can be achieved through application of "systems technologies" to other elements of building.

- examples studied in the New York City area use simple assembly and insulating methods which may not be directly applicable to Canada;
- L.M.F. offers a competitive method of construction for intermediate rise projects three to six stories from the examples studied;
- additional advantages in the use of L.M.F. systems should be realized in areas where foundation or building loads are critical.

2(ii) Brief History of Light Metal Framing

From the authors' discussions with various members of the industry in Canada and the U.S., the following would seem to be a realistic account of the development of the industry in the U.S.

The product lines of cold rolled steel joists and cold rolled steel studs were developed by steel suppliers and fabricators in the U.S. in the 1950's. One of the principal companies which participated in the development of L.M.F. was Wheeling Steel of Wheeling, West Virginia. At its outset, both in Canada and the U.S., the product lines were targeted at residential builders and did not differentiate between single family housing builders

and multiple unit builders.

At this time, typical details, application methods, equipment lists and engineering data were provided by various companies, in particular Wheeling Steel, in order to facilitate the use of their product lines by contractors. However, due to the nature of the systems and in order that projects could be manufactured and erected, the steel manufacturers began to provide complimentary engineering services with their products.

For the most part, the original companies targeted were drywall contractors as the constructors of their systems. Due to the unsophisticated skills and the business practice of drywall contractors, all detailing was simplified and an emphasis was put on simple connections with power screw assemblies.

Through the 50's and 60's, projects proceeded on a piece meal basis throughout the industry, with the steel companies participating at every stage of the contracts. Through this time period none of the contractors originally enticed into fabrication and erection of L.M.F. took on this building system as their principal business. All contractors were in fact primarily involved in other trades and L.M.F. was simply a side-line.

In the late 1960's, in both Canada and the U.S., renewed interest was developed around L.M.F. This was due principally to the rapid growth of the housing industry through this time period and the demand in world markets for lumber. It was felt by many steel companies and fabricators that the trend through the 70's would result in standard wood frame construction pricing itself out of the market and thus all participants were searching for substitutes to be used in both single family residential units and multiple residential unit construction.

At this time a great deal of promotion and product development was taken on by steel producers such as Stelco in Canada. Other L.M.F. systems were developed by Alcan and an export market was also identified and pursued by various Canadian companies.

The development of the industry in the U.S. during the 70's, however, took a slightly different pattern. Due to the inability of the fabricating and steel companies such as Wheeling to make a marked penetration of residential construction industry in the U.S., a different emphasis was placed on the development of the industry. It was identified that perhaps the weakest link in the industry was the contractor or the executor of the projects.

At this point a more sophisticated contractor was encouraged to enter the market place. In some cases these were independant engineering/contracting firms and in other cases subsidiaries were set up by such companies as Inland Steel to act as engineers, fabricators and erectors of L.M.F. systems. In this case, Inland participated in a company called Mycor from Minneapolis.

The new companies which entered the construction portion of the industry were sophisticated systems contractors. Their services included engineering, detailing, manufacturing and erection capabilities. This change in the industry solved the gap which had previously existed between design and implementation of the framing systems. The problem which previously existed in the industry was that an information gap existed between the engineers or designers retained as consultants of a particular project and the contractors.

Steel companies such as Wheeling had provided free or subsidized engineering services in order that contractors could advance a project from schematic engineering and design drawings to shop and erection drawings that were required in order to execute the project. They have now discontinued this practice.

At the present time in N.E. United States, there exists a fairly healthy and complete range of suppliers, fabricators and contractors in the L.M.F. industry. Through the development of numerous participants in each portion there is a competitive market for materials of the industry and services. This has also resulted in a more sophisticated approach to the building systems, where pre-assembly of panels and components is possible, and for complicated or large projects, single contractors can rely on other assembly shops in order to augment their fabrication and supply capabilities.

There is also developing in N.E. and S.W. United States a more sophisticated use of complimentary cladding systems and in some instances pre-assembly of insulation, cladding, wiring, windows and door frames at the factory for assembly of the panels.

The industry, throughout its history, has also been preoccupied with problems of competing unions and trades for work in the markets. At the industries outset, it was felt that sheet metal workers or drywall trades would be best suited to work with L.M.F. Other attempts were made to use steel workers or iron workers for the installation of the systems due to the welding and need for comprehension of shop drawings. However, at this time, the most successful portions of the industry

are in fact using what we might call construction labour unions or carpenters rather than other trades which one would assume would be more familiar with steel construction. This is due to the lower wage rates possible with union carpenters and in the opinion of many industry participants a greater willingness to adopt to new technology. Although examined in some detail later in this paper, it is sufficient to say at this time that the skills required in order to work with L.M.F. are simple and training period required is rather short.

2(iii) Summary

- early efforts by suppliers and manufacturers of L.M.F. systems to compete with wood construction in the residential market were not successful due to the fluctuating lumber prices and the splintered nature of the industry;
- early efforts to entice other trade contractors into the market failed due to the complexities of skills, services and the need for sophisticated construction management in order to build in L.M.F.;
- the second generation of L.M.F. contractors combined engineering, technical skills, pre-manufacturing capabilities and design service in order to compete in the market;
- successful application of L.M.F. required pre-manufacturing of components;
- site and manufacturing labour can be trained easily in the skills necessary for L.M.F.;
- the primary design of residential projects requires a conversion to L.M.F. designs from conventional construction consultants documents;
- contract payments and forms may vary in L.M.F. projects due to the nature of pre-assembly and supply.

3. THE INDUSTRY IN 1982 IN THE U.S.A.

(i) Current typical job profiles

A typical project starts with a small residential building which is usually designed in masonry or concrete construction. At some point the project is re-examined and preliminary details and costing is sought for conversion to L.M.F. It would appear from the authors' examination of the industry in the U.S. that few projects begin with a dedication to L.M.F., and that the majority in fact are converted to this type of construction after preliminary work has been done in another construction system.

At this point, the architects and engineers associated with this job are usually not familiar with L.M.F. and either the product supplier or the contractor has to convert detailing and design to a compatible mate with L.M.F. This redesign involves adjustment of spans, material components, use of

modular dimensioning, revision of assembly details, and in particular coordination of the mechanical services with L.M.F. requirements.

Through this period, the contracts are usually negotiated or eventually become a labour and material type of contract rather than a whole tendered contract. In part, this is due to a lack of competitive contractors in some areas, and also to the fact that each project is usually detailed in a fashion unique to the preferences of a particular contractor.

Contracts are also usually negotiated on a different payment schedule from typical construction. This is due to the fact that payment is required for materials delivered to the assembly shop rather than materials supplied to a job site, in order to pre-fabricate panels.

Typical projects range from three to five stories in height and at this time include complimentary system detailing for exterior panels comprised of brick, aggerite finishes, stucco, and metal siding.

3.(ii) Popularity in the Market

From the authors' brief survey of sales agents in the condominium market of L.M.F. units, it appears that there is a broad acceptance by the public in the U.S. for this type of construction. From discussions with the sales agent it would appear that comments made are, in general terms, that steel stud and metal joist construction represents better "quality" to the general public and when used with non-combustible construction, it represents "fireproof" construction to the public.

Internal layouts of the units seem to benefit from the longer spans and other flexibility offered by the framing systems.

Surprisingly enough, acoustic problems, or the solid wall desire, does not seem to be a problem in the public's examination of these units. From discussions with builders and developers in the U.S., it is the authors' general opinion that L.M.F. represents quicker erection times to the developer, that to him greater freedom of unit layout and design is possible than with other systems in low volume projects.

From the authors' experience in the export market of Canada, it would also appear that L.M.F. is enjoying some success as an export form of housing. This is due to its component system quality, non-combustible construction and resistance to moisture and vermine.

In both the export and domestic American market, it would appear that L.M.F. enjoys an aesthetic advantage, where truss roofs or mansored roofs are easily designed and constructed, thus fitting with current aesthetics involving traditional building, massing and profile.

3(iii) Summary

- there is no evidence found in our study of current projects of consumer resistance to this construction method;
- L.M.F. systems represent "fire-proof", durable and aesthetic construction to the general public.

4. TYPICAL COST CALCULATIONS

4(i) Typical unit cost guidelines

For this sample exercise, a number of assumptions have been made regarding the example costs shown. All costs shown in the example are given in U.S. dollars as of November 1982. It must be noted that for labour and material supply rates as of November, 1982, the author has found a direct correspondance between American values stated and Canadian dollars, i.e. ten dollars American translates to ten dollars Canadian for labour and material supply. This is acknowledged to vary with an advantage to the Canadian material supply prices diminished in some market conditions.

4(ii) Material Supply

Current informal enquiries between American and Canadian suppliers of rolled steel products indicate a direct cost for the product between U.S. dollars and Canadian dollars, disregarding exchange rate differences. During November, Canadian suppliers were contacted by the author and compared against average supply costs by the American. For the purposes of this exercise, and average cost/m^2 of $26.87 ($2.50/sq.ft.) is used. Furthermore, an average supply cost of $26.87/$m^2$ ($2.50/sq.ft.) is assumed as a blend of wall and floor material required in relationship to the square foot of finished floor area to be constructed. This value is assumed as a blend between the Glenpoint project and the Bushwick II project, also documented in this study (see V(iv), V(v)).

4(iii) Typical Unit Size

As the examples studied varied, typical unit sizes varied from 93m^2(1000 sq.ft.) to 205m^2 (2200 sq.ft.). For the purpose of this exercise an average unit size is assumed to be approximately

Unit construction is also set to be completely non-combustible construction with poured concrete floors on steel pan.

Steel roof construction is also assumed to be load bearing joists with a flat roof.

4(iv) Engineering Services and Shop Drawings

From cost comparisons on the projects documented in the conversations with engineers and contractors supplying these services, it may be assumed that the average square metre cost of built floor area for typical apartment construction results in an additional charge of approximately $1.08/m^2$ (10¢/sq.ft.) for erection and fabrication drawings. It is assumed taht these have been developed from base architectural and engineering drawings.

4(v) Shipping Costs

Shipping costs for non-prefabricated material to job sites is assumed within the square metre material supply cost. For prefabricated panels, the shipping costs will vary as a result of the project location, and in the examples studied varied from $2.58/m^2$ (24¢/sq.ft.) to $75¢/m^2$ (7¢/sq.ft.). In order to arrive at an average cost for this, as Canadian and U.S. samples may change, shipping companies in Toronto were contacted, and for an average 13.5m (45') float of panels stacked 2.4m (8') high, the cost for delivery within an 80 km (50 mile) radius within the factory would be approximately $54¢/m^2$ (5¢/sq.ft.). Each load was quoted at $213.00/load.

4(vi) Building Costs for a $465 1m^2$ (50,000 sq.ft.) Floor Area, Residential Building

A. Wall panel, pre-assembly:

Assume 1.02 man hour/m^2 (1/10th man hour/sq.ft.) of building area. In a $465 1m^2$ (50,000 sq.ft.) floor area, assume an equal amount of wall area for load bearing interior and exterior walls. Therefore, 5,000 hours will be required to produce wall panels. At a total rate of $15/hour, assuming a direct labour charge of approximately $8/hour, the total cost for fabrication would be $75,000. This figure would include profits and overhead.

B. Erection of wall panels and on site construction of floors, including joists, miscellaneous beams, and floor pan:

Assume 1.02 man hours/m^2 (1/10th man hour/sq.ft.) of floor area to be constructed, or 5,000 hours total.

Unit rates for on-site construction are assumed to be $25/hour, resulting in an on-site erection cost of $125,000. Included in this cost are all profit, overheads and miscellaneous charges required for the erection of floors and walls.

C. In this example it is assumed that the floor panels are also pre-fabricated as well as the wall panels:

For floor panel costs see "A" above, which is given as $75,000.

For panelization of floors, assume a labour productivity rate of .86 man hours/m^2 (.08 man hours/sq.ft.) of panelized floor. At an hourly rate of $15/hour this results in $60,000 for panelized floor construction. For erection of floor panels and wall panels, assume .54 man hours/m^2(.05 man hours/sq.ft.) of constructed floor area, as a man hour estimate. At $25/hour on site construction cost, this would result in $62,500 in costs.

The cost comparison between panelization of walls and on site construction of floors versus panelized floor and wall systems is approximately a $2,500 difference. Additional charges are added to the comparison of transportation of floor panels to the site. The $2,500 difference is negated.

4(vii) Conclusion

The cost differences illustrated between shop prefabrication of wall panels and factory fabrication of floor panels demonstrated that in theory there is not a difference between prefabrication of floor panels or stick built construction of floors on site. This may also, for simple buildings, be translated into a negligible difference for on site construction of wall panels or shop prefabrication of wall panels.

Differences, however, are found when labour costs vary and other considerations are taken into account. These include project timing, local labour productivity rates, winter construction, and site conditions. Each job must be examined by the contractor and appropriate methods chosen for each type of construction.

In this exercise of costing a typical 465 m^2 (50,000 sq.ft.) building, it should be noted that the cost for all items given may vary 20% above and below the figures given, depending upon the individual conditions of each project. These may be principally influenced by unit sizes, configurations, complexity of the structural layouts.

For the sake of this exercise, two examples studied may be used as a comparison for a simple versus complex building configurations. The Glenpoint condominium project is an example of a complex configuration and would require an additioal 20% to be added to the exercise. The Washburn II would be an example of a simple configuration and would result in a savings of 20% from the figures used in this example exercise.

The question of productivity rates assumed has also a bearing on the transposition of this sample exercise into other regions of Canada. It must be noted that the construction productivity rates in the New York City area would be amongst the highest in

North America. From informal enquiries by the author, it is assumed that these productivity rates could be used for the Toronto area, but may vary dramatically outside the Toronto area, in other regions of the province, and in Canada.

Total costs for labour in methods shown in A and B are $200,000. On-site labour is 5,000 hours at $25/hour. Off-site or prefabrication labour is 5,000 hours at $15/hour.

For the variation shown in method C the total cost is $197,500. On-site labour is 2,500 hours at $25/hour and off-site labour is 9,000 hours at $15/hour.

Note: The following estimate and productivity rates were supplied by R.H. Kilmer Inc. The author requested for labour rates, those charges which represent all wages, overheads, profits and benefits. The author would like to draw the readers' attention to a difference in the calculation of total charges, of wages times approximately 1.5 for site labour versus wages times approximately 1.9 for factory rates.

4(viii) Project Cost Breakdowns:

Assuming 50,000 finished floor area -

i) Engineering services and shop drawings	$5,000.00
ii) Shipping costs, method A & B	2,500.00
alternative C	5,000.00
iii) Fabrication costs	
method A & B	200,000.00
method C	197,500.00
iv) Material costs	125,000.00

Total A & B = $332,500.00
Total C = $332,500.00
average/square foot = $6.65

Using a plus or minus difference of 20%, this would result in a $5.32/sq.ft. charge to a $7.98/sq.ft. charge, depending on project factors.

4(ix) Cost Data Sources

The following are cost data sources for this exercise:

1) R.H. Kilmer Inc., for labour and productivity rates for the fabrication of light weight metal framing. Local labour rates have been taken from various industry sources and checked with local union labour rates.

2) Material prices have been obtained from local Canadian suppliers, and for the most part represent a material plus mark-up.

3) Drywall prices for the Toronto region have been obtained from the 1981 Yardsticks for Costing, published by Southam Publications, and checked with local drywall installers.

4) Masonry prices have also been taken from the 1981 Yardsticks for Costing, and cross-checked with local masonry contractors.

In the drywall and masonry prices, considerable difference has been found between some prices given in the Yardsticks for Costing manual and those obtained directly from local contractors. The reason given for these discrepancies is a difference between residential and commercial construction prices, as well as hourly labour rates.

4(x) Summary

- at this time (November 1982) a range of suppliers is available in the central Canadian market, assuring some degree of competitive supply.
- engineering drawings or shop drawings should be generated by the L.M.F. contractor as part of his job.
- shipping costs of pre-assembled panels is a minor portion of total costs of a project.
- cost advantages in pre-manufacturing of panels is dependant on many factors and can not be assumed to offer direct savings in every project.
- each project cost is dependant on its own complexities and characteristics with a possible cost variation of ± 20% as compared to typical applications.

5. SAMPLE COSTING

For this exercise, two unit types have been chosen, which consists of a motel unit of approximately 3.9m x 7.8m, and a housing unit of approximately 8.2m x 10.2m. The two modules have been chosen to test a partition and exterior wall to floor ratio, and to test some of the additional costs which can be apportioned to each type of construction. In each example, the exterior veneer cladding has not been estimated in the construction costs of the unit. It is assumed that this would be constant in both construction methods.

In the examples the unit costing examines the primary structure in either L.M.F. or masonry, and the interior wall finishes in drywall or plaster. Each example is taken to be a four storey building with load bearing partitions between each module. Additional costs are attributed in masonry construction to drop ceilings required for kitchen and bathroom areas, and an additional roof cost apportioned

to each unit as a result of slightly higher construction costs to achieve the same thermal insulation and quality of construction.

In the L.M.F. examples, a higher grade of construction has been assumed for drywall finishing, in that two layers of drywall have been used for party walls. This has been done for reasons of sound insulation, where a single layer would meet required fire and sound ratings.

Some secondary construction, such as crane time for both brick and block construction, pre-cast slabs and the L.M.F. have not been included in either examples. Shop drawings, transportation to the site, and supervisory time has not been included in the L.M.F. example. Masonry construction has been assumed to be at commercial rates and a reduction may be assumed in some residential projects. All labour rates are taken for the Toronto area, and in particular in the masonry costs one may assume a 10-20% cost difference for masonry construction in neighbouring regional areas such as Peterborough or Hamilton over Toronto costs. In general, the costs shown in this example are given as a guide to the relative cost differences between L.M.F. and masonry. In actual projects these may vary as to local conditions at the time of tendering.

6. EXAMPLE A

The sample costing in this example examines the construction of a motel unit of approximately 3.9m x 6.0m. The following floor and wall areas are used:

a) wall area- party wall 14.88m^2 (160 sq.ft.)
b) " " - entrance wall 5.77m^2 (62 sq.ft.)
c) " " - exterior wall 5.58m^2 (60 sq.ft.)
d) floor area 18.60m^2 (200 sq.ft.)

6(i) Summary of unit costs for Masonry construction

a) 160 x 5.29 = $846.4
b) 62 x 3.65 = 226.3
c) 60 x 5.17 = 310.0
d) 200 x 3.95 = 790.0
e) 40 x 1.17 = 46.8
f) 25 x 1.19 = 29.75
$2249.75

Unit price breakdowns are derived from the individual prices shown below. These are meant to include all secondary costs but do not include profit and overheads.

6(ii) Masonry Construction-detail construction and costing

Exterior wall construction:

insulation	- 80 mm blue board	21.50 m^2
block	- 90 mm	29.00 m^2
drywall	- 12 mm (laminated)	5.16 m^2
		55.66 m^2
		= 5.17 sq.ft.

Interior wall portion load bearing:

block	- 190 mm	35.00 m^2
drywall 2 sides		
	(12 mm plus furring channels)	19.78 m^2
		54.78 m^2

Interior partition wall:

block	- 90 mm	29.00 m^2
drywall 2 sides		
	(12 mm laminated)	10.32 m^2
		39.32 m^2

Roof construction (additional cost to masonry):

insulation	100 m styrene	14.50 m^2
	100 m conc (lightweight)	8.30 m^2
		12.80 m^2
		= 1.19/sq.ft.

Suspended ceiling construction:

ceiling grid	8.50 m^2
drywall (supply)	1.19 m^2
drywall (installed)	2.15 m^2
	12.55 m^2
	= 1.17 sq.ft.

Floor ceiling construction:

concrete slabs 204 precast	35.00 m^2
spray plaster	7.50 m^2
	42.50 m^2
	= 3.95 sq.ft.

7. EXAMPLE B

The areas taken for this example are the same as in example A. Assume a 3.9 x 6.0m unit.

7(i) Unit costs for L.M.F.

a)	160 x 4.46 =	713.6
b)	62 x 2.74 =	169.8
c)	60 x 4.14 =	248.4
d)	200 x 4.18 =	836.0
		$1967.80

The cost for the production of this unit is $1,967.80 for L.M.F. versus $2,249.75, or a difference of $287.75.

7(ii) L.M.F. Detail Construction and Costing

Floor,Ceilings:

steel joists	28.59 m^2
22 ga. steel	3.92 m^2
16 drywall installed	5.13 m^2
conc. toping 50 m	7.35 m^2
	44.99 m^2
	= 4.18/sq.ft.

200mm steel joists (16 ga) =
1.40 x .9* = 1.26* - simple # reduced by 20
.064* x 15 = .96
.04 x 25 x .5* = 50*
- erection of floor 1/2 total
Total: 2.66 = 28.59

Wall panel assembly:

material .915* x .9 =	.8235
assembly labour	.96
site labour	.50
	2.28 sq.ft. = 24.51 m^2

Partition walls:

panels (installed)	24.51 m^2	
drywall - 2 layers both sides	20.80 m^2	
bath insulation	2.65 m^2	
	47.96 m^2	= 4.46 sq.ft.

Exterior wall panels:

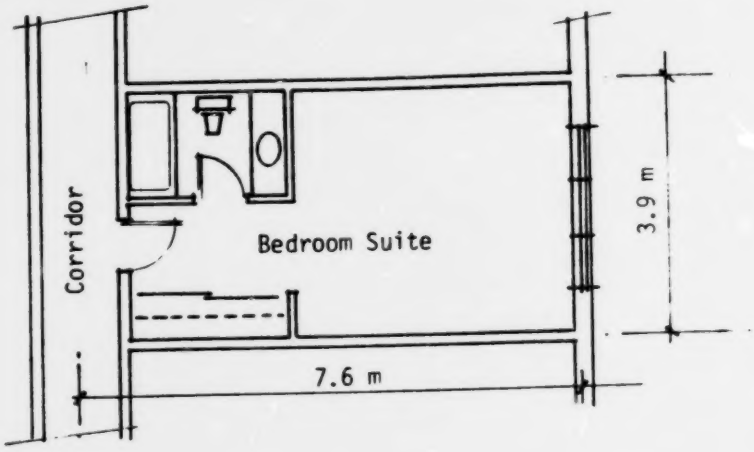
71 x 1.33 =	.94 m^2	
	.96 m^2	
	.50 m^2	
	2.40 m^2	
panels installed	25.80 m^2	
insulation	7.95 m^2	
exterior dyp	6.05 m^2	
interior drywall	4.75 m^2	
	44.55 m^2	= 4.14 sq.ft.

* blended cost

Weight Comparison of L.M.F. to Standard Masonry Construction

Typical Unit:

3.9m wide x 7.8m to centre line of corridor



L.M.F. Construction

Floor:

7.8m x 3.9m = 30 SM	
79m of floor channels at 6.26 kg/SM =	495 kg
Concrete and deck, 30 SM at 87.8 kg/SM =	2634 kg

Ceiling:

7.8m x 3.9m = 30 SM	
2 layers of 12mm gypsum board at 19.5 kg/SM =	585 kg

Bearing Walls

7.0m x 2.4m = 16.8 SM of 100 mm steel stud partitions.	
44m track and bridging = 65m at 1.95 kg/m =	126 kg

Interior Partitions:

60mm studs and 12mm gypsum drywall, each side, 17 SM at 20.5 kg/SM =	348 kg
PER UNIT TOTAL DEAD LOAD	4188 kg
Required O.B.C. Live Load: 195 kg/SM x 30 SM =	5450 kg
TOTAL	10,038 kg
Weight for five floors of construction: 10,038 kg x 5 =	50,190 kg
Snowload: 244 kg/SM x .8 (flat roof) x 30 SM =	5856 kg
TOTAL WEIGHT	56,046 kg

For shear wall construction with 7.8m of footings:

600mm wide footings = 56,046 kg/4.62 SM
= 12,131 kg/m
760mm wide footings = 9,577 kg/m

8. MASONRY CONSTRUCTION

Floor:

200mm hollow core slab, 30 SM at 146 kg/SM = 4380 kg

Bearing Walls:

2.4m x 7.0m = 16.8 SM at 195 kg/SM = 3276 kg

Interior Partitions:

60mm stud and 12mm gypsum drywall, each side
16.8 SM at 20.5 kg/SM = 344 kg

PER UNIT TOTAL DEAD LOAD 8000 kg

Required O.B.C. Live Load:
195 kg/SM x 30 SM = 5850 kg

TOTAL 13,850 kg

Weight for five floors of construction:
13,850 kg x 5 = 69,250 kg

Snow Load:
244 kg/SM x .8 x 30 SM = 5856 kg

TOTAL WEIGHT 75,106 kg

For shear wall construction of five floors with 7.8m of footings:

600mm wide footings = 75,106 kg/SM
= 16,256 kg/m

760mm wide footings = 12,834 kg/m

For four floors:
600mm wide footings = 61,256 kg/SM

760mm wide footings = 10,467 kg/SM

It is assumed that the exterior wall is supported on its own strip footings and so does not place any loading on the shear walls under construction.

The dead load of L.M.F. construction material at 4188 kg/hotel unit is approximately 52% of the weight for masonry construction at 8000 kg/ hotel unit.

For L.M.F. we have drywall finishes throughout, and for masonry we have exposed conc floor slabs and conc bearing walls should strapping and drywall finish be required for wall finishes. The weight for masonry would increase approximately 4½%.

9. CONCLUSIONS

From the authors' study of medium density residential projects which have been constructed or are under construction at this time in the New York City area, and a thorough examination of L.M.F. systems in terms of material, technical details, fabrication and erection techniques and typical unit costs, it is seen that L.M.F. has gained a broad acceptance by the public in the United States and that the system has the flexibility for adaption to gain acceptance within the Canadian market in the near future.

At the outset of the L.M.F. appearance in the building industry in Canada, before economies of scale can be realized by broad market application and competitive tendering, projects must be simple, have repetitive unit configurations at a scale of between 2,500m^2 to 5,000m^2 before some of the secondary costs such as working drawings, construction supervision, shop drawings and construction administration costs can be absorbed in a project. The more repetitive the configuration, then the larger the potential for a "systems" approach to pre-fabrication of all other elements involved in the building, such as prewiring of electrical systems, plumbing elements, exterior wall panels, etc. This system of L.M.F. can be easily built to non-combustible construction standards and thus conform to standards enforced for buildings greater than three stories in residential uses, as required by Canadian codes. The advantages usually attributed to wood frame construction, such as simple erection, freedom of design, low foundation loads, inclusion of large "R" values of insulation within the exterior wall panels, ease of incorporation of plumbing, electrical systems, and economic construction are also possible at an intermediate density and height.

In respect to thermo design of roofs/walls and vapour transmittion design, which is of greater importance in terms of construction in Canada, L.M.F. has a substantial advantage over masonry construction which has traditionally been used for buildings in the medium density, four to six stories in height. The system lends itself to a "blanket" configuration of exterior walls and floors which completely "wraps" the structure in an insulation and vapour barrier in which the exterior walls can bypass interior load bearing elements and thus minimize problems of interior/exterior thermo transmittion and interruption to the vapour barrier. With exterior cladding systems that are compatible with L.M.F. designs, such as composite panels of stucco, wire mesh, rigid insulation, steel, vinyl or aluminum sidings, G.R.C. panels or even brick veneer, the exterior wall sections are greatly reduced in weight over standard masonry or poured concrete construction, and connection details to interior elements are greatly simplified.

The reduction in weight of approximately two thirds of the deadweight of the building makes L.M.F. attractive for parts of the country with high earthquake loads. It is possible to build medium densities which can be tied together with diagonal bracing in partitions and floors to eleviate some of the problems experienced in other forms of construction in earthquake areas.

It is the authors' experience that there has recently been a growing resistance in M.U.R.B. projects and condominiums to highrise structures of over eight stories in height. This is partly due to escalating maintenance costs and public dependance on common services and spaces. It is our belief that in the near future we will see the return of walk-up configurations of buildings that are from three to five stories, where less emphasis is placed on elevators, common spaces, mechanical systems, common services (domestic hot water, heating, air conditioning, etc.).

As a last point, it can be seen that there is a growing resistance in the total redevelopment of existing residential neighbourhoods to either highrise housing or to developments that exceed approximately 1.5 times the lot coverage. The new emphasis seems to be on medium height and density residential redevelopment with "infill" housing introduced into existing neighbourhoods. This is particularly evident in large urban areas and the advantages of L.M.F. in construction is increasingly making it an obvious and ideal choice.

10. PROJECT EXAMPLES

10(1) PROJECT NAME: Fountainhead Apartments

PROJECT ADDRESS: Central Park Avenue
Town of Greenburgh, N.Y.

OWNER'S NAME & ADDRESS: D.H.I. Enterprises Inc.
984 North Broadway,
Yonkers, N.Y. 10701

DEVELOPER/GENERAL CONTRACTOR NAME & ADDRESS: D.H.I. Enterprises Inc.
Same as above

ARCHITECTS NAME & ADDRESS: D.H.I. Enterprises Inc.
Same as above

TYPE OF UNITS: Co-op

NUMBER OF UNITS: 108

NUMBER OF BUILDINGS: 2 + commercial building

TOTAL LIVING AREA: 129,998 sq. ft. (does not include community areas)

SITE AREA: 180,774 sq. ft.

NUMBER OF STORIES: 4

LIGHT METAL FRAMING ITEMS INCLUDED: total L.M.F. structural system including all exterior walls, interior bearing walls, floor joists and roof rafters

LIGHT METAL FRAMING PRICE: $840,000 (winter 79-80)

COST ESTIMATE BREAKDOWN:

Material -	$412,000
fabrication -	95,000
shipping -	10,000
engineering and S.D. -	20,000
erection:	
panels -	174,000
joist -	80,000
deck -	52,000

MAN HOUR SUMMARY: Erection M.H. = 13,128 m.h.

GENERAL COMMENTS:

	Total	per sq. ft.
Material supply	$412,000	$3.17
fabrication	95,000	.73
shipping	10,000	.076
engineering and shop drawings	20,000	.15
erection	306,000	2.36
panels	174,000	1.34
joists	80,000	.62
deck	52,000	.40

erection man hours 13,128 m.h. - $23.30 / hour - 2.36 / sq. ft.

The Fountainhead Apartments

The Fountainhead apartment co-operative is comprised of approx. 108 units in two 4-storey buildings constructed in the town of Greensburgh, New York. The light metal framing portion of the project was completed during the fall of 1979 and early winter of 1980.

The total area of the project is 130,000 sq. ft. of living area. Unit sizes vary from 790 sq. ft. for one-bedroom units to 2,300 sq. ft. for three bedroom units.

The configuration of the buildings represents the most complex examples of metal steel framing examined in the N.Y. area. Numerous balcony and room projections are used in the layout of the units and result in a complicated facade configuration.

The construction of the building utilizes masonry and concrete podium construction to accomodate interior parking and resolve complicated slope conditions of the site. Above the parking podium is constructed 4 stories of light metal framing to contain the accommodation units. Although some pre-fabrication was completed prior to delivery to the site, the majority of work in this project was comprised of on-site construction and erection of light weight metal frame members.

The floor system within this building is a plywood sub-floor system and is perhaps unique in the examples visited for the use of this type of floor system in a project of this size.

Other conditions which make this somewhat unique example are the use of aggregate panels and standing seam metal panels for rooves and walls. The majority of these are simply screw or bolt attached to light weight metal framing and a plywood backup.

In the analysis of the cost estimates provided for this project, it is worth noting that the material supply cost is perhaps higher than the other examples, and in part it is due to the use of plywood for the floors, which is contained in this price.

The total square foot cost lies in the upper mid-range of average sq. ft. costs of the examples studied, at $6.48/sq.ft. This, however, must be pro-rated, from 1979 construction dollars to 1982 construction dollars for the Glenpoint, Bushwick and Boatyard projects.

It is interesting to note that one of the reasons for the choice of the system given in promotional material were the seismic design requirements for the New York area. "Seismic design requirements are met by utilizing LMF, sheer walls connected by bolted and welded assemblies to the structural steel garage level. Framing to miminize floor deflection. We incorporated continuous joists with three point support in the design".

Other comments from promotional material were made by the construction supervisor, who had indicated that he felt that the light weight of the panels made them easy to handle and increased field production. "He feels the job would have been economically unfeasible in masonry." He also claims that the electricians and plumbers saved a tremendous amount of time because of only a few holes needed to be burned in the deck, compared to drilling a vast number through wood or masonry.

SUMMARY

- the cost per square foot attributed to LMF of $6.48 in 1980 construction dollars, when adjusted to current dollars at a 10% increase per year would result in a cost of approximately $7.80 per square foot, and thus is at the + 20% range from typical construction costs. This is a result of its complicated configuration and massing.
- this project is a good example of the integgration of other cladding systems with LMF.
- due to the complicated nature of the project, detail breakdown and analysis of cost components has not been attempted.

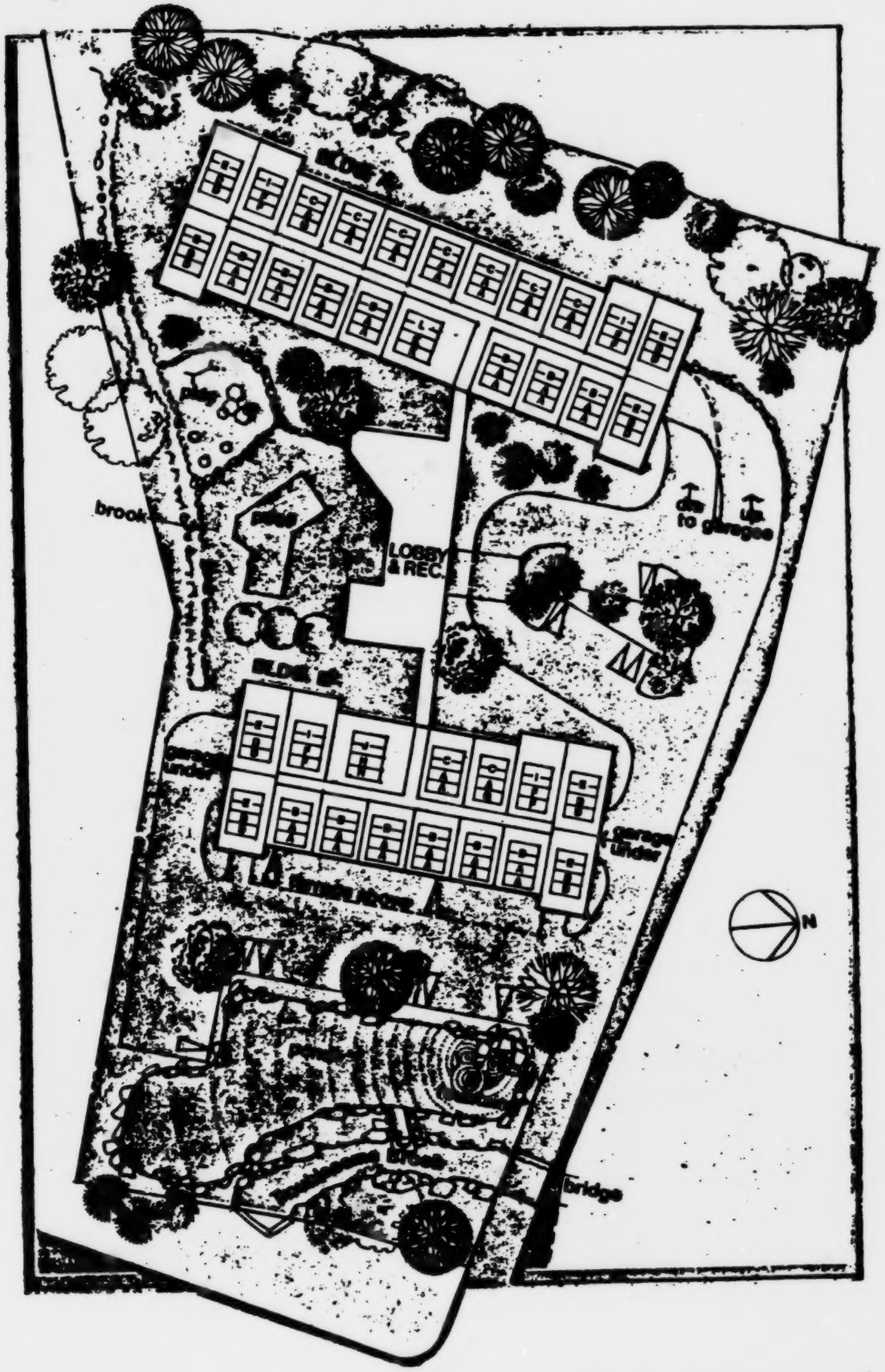
Illustrations, Fountainhead Project

#1 - Site plan

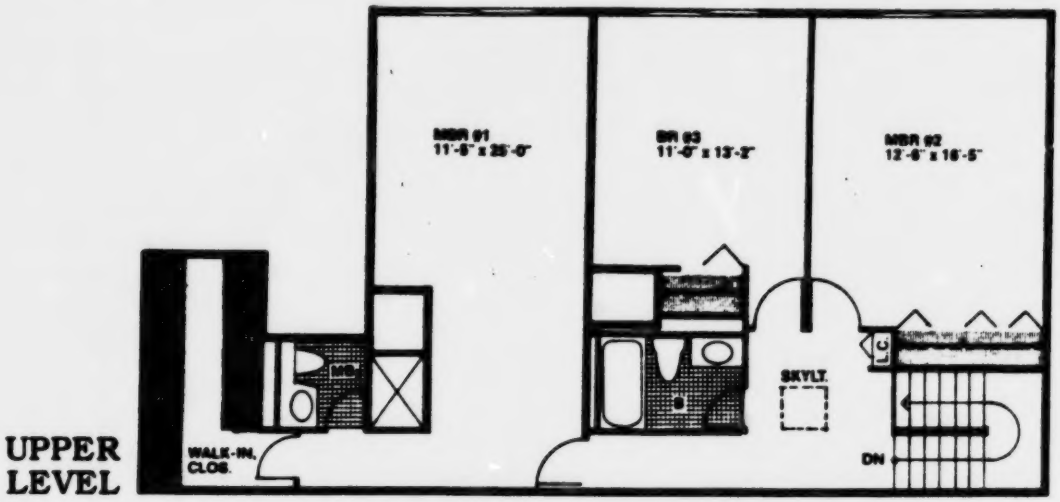
#2 - 6 - Typical unit plans

#7 - Rendering

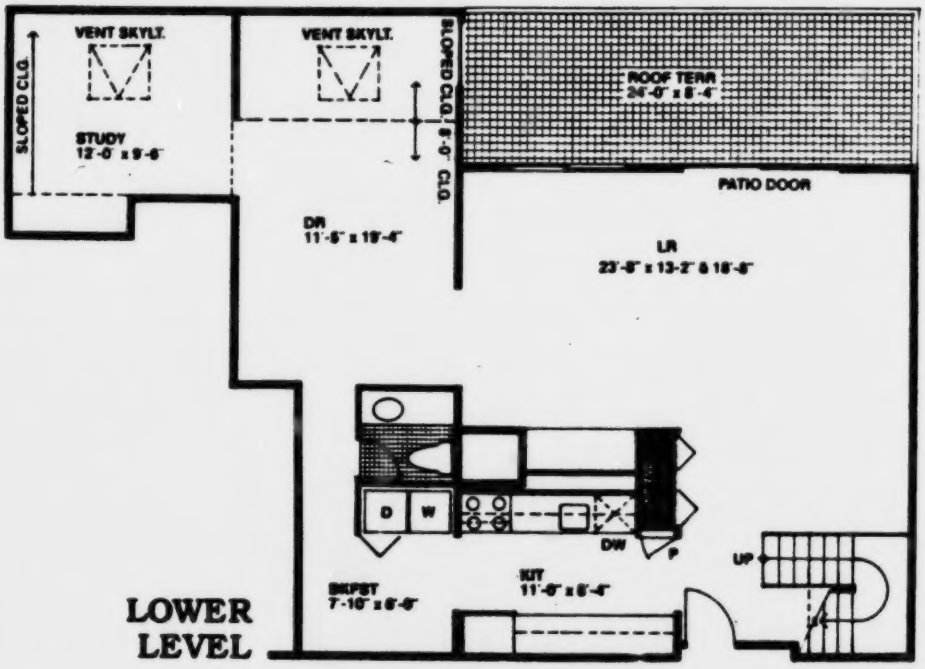
#1


BLDG. A
play
brook
LOBBY & REC.
BLDG. B
to garages
garage under
N
bridge

#2

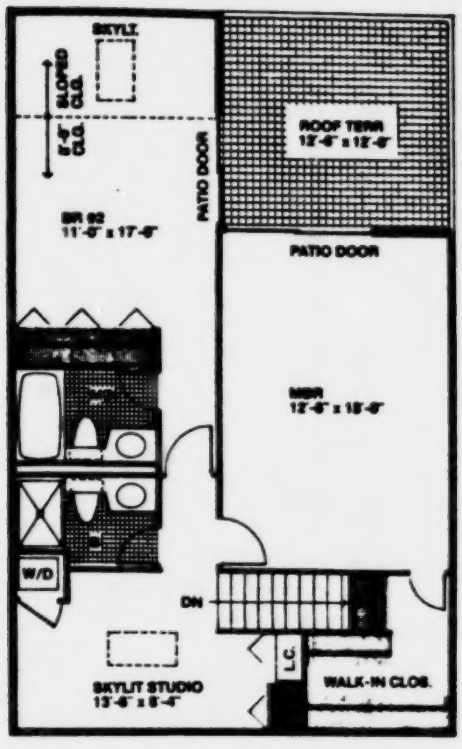


UPPER LEVEL



LOWER LEVEL

#3



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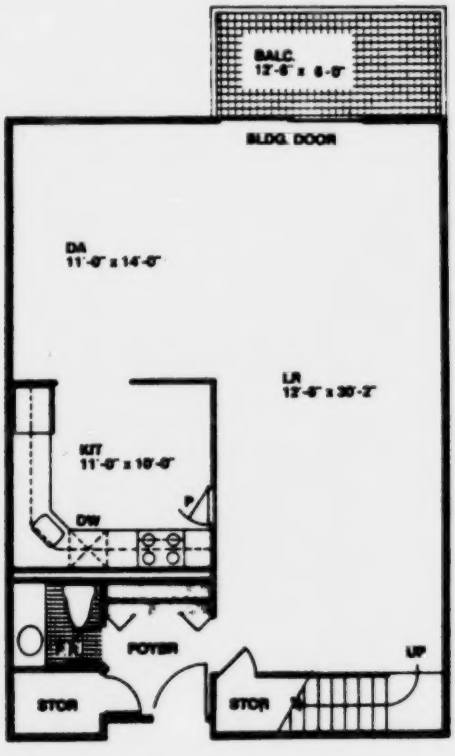

LOWER LEVEL

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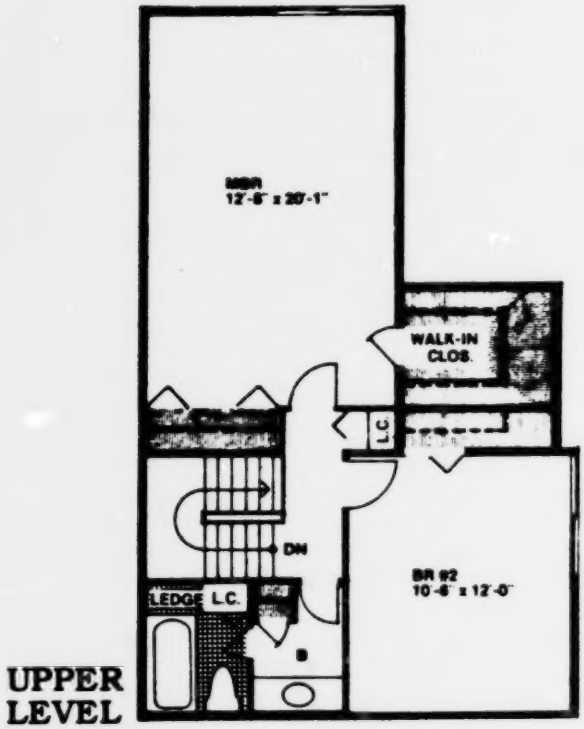

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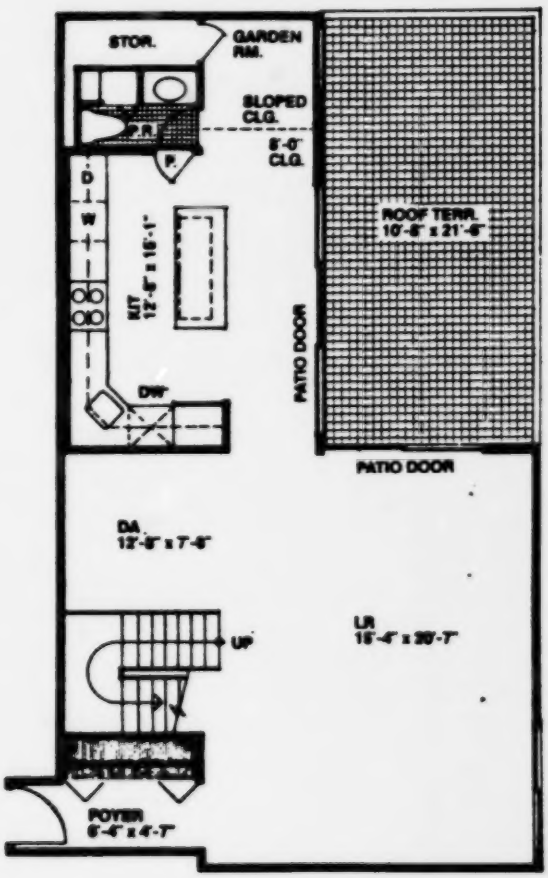

LOWER LEVEL

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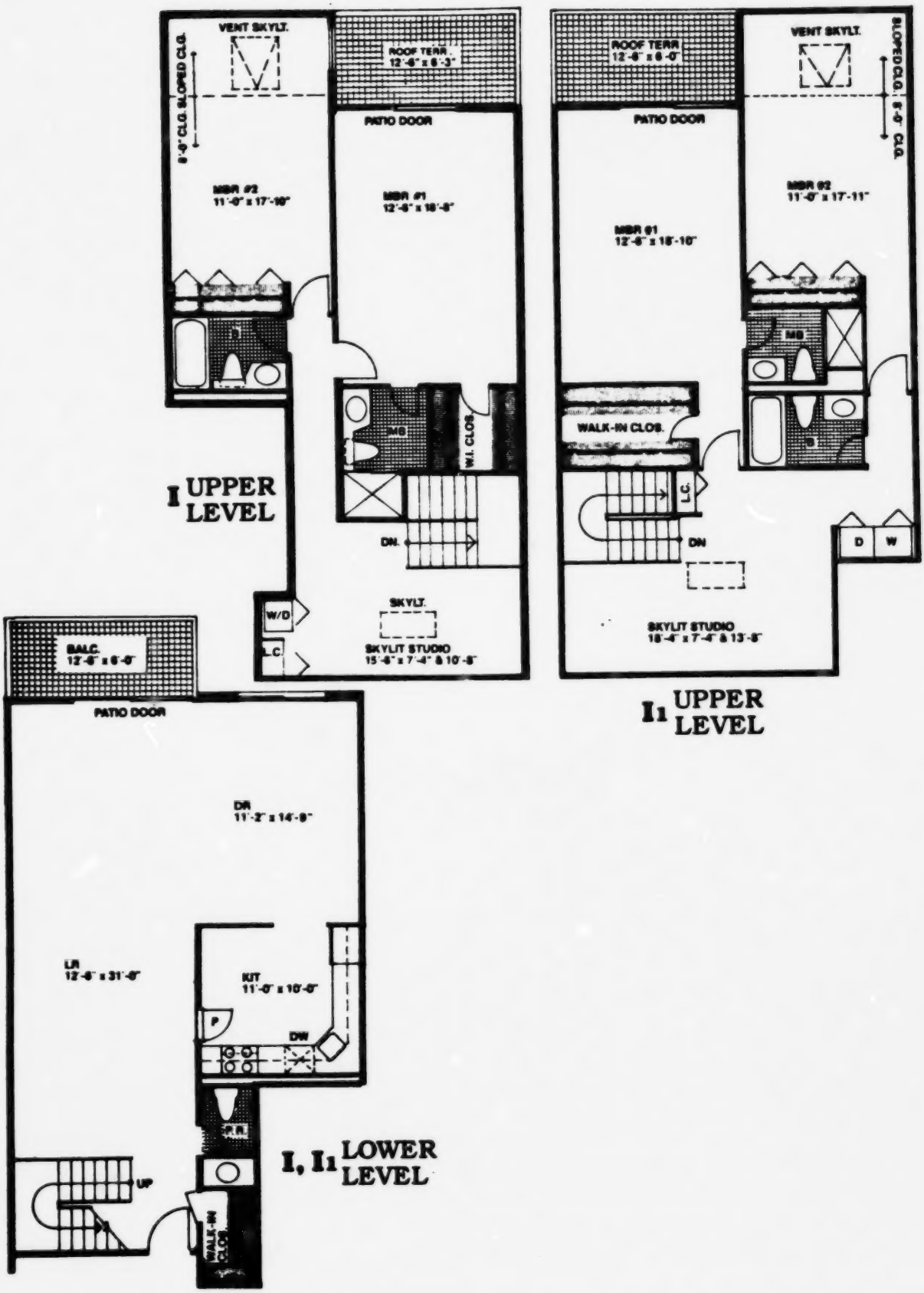
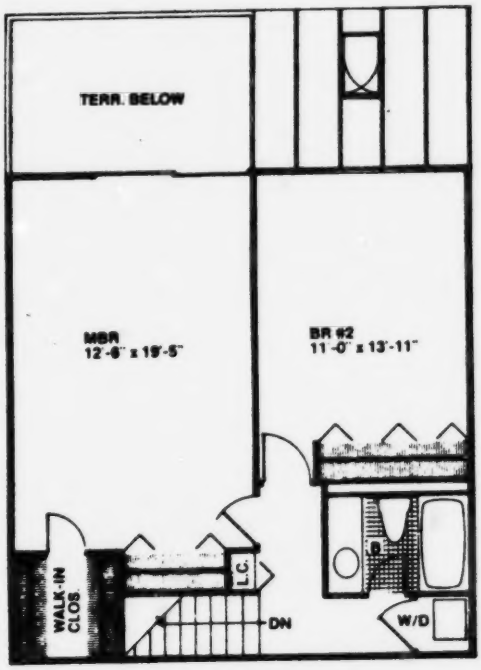

VENT SKYLT.
8'-0" CLG. SLOPED CLG.
ROOF TERR.
12'-6" x 6'-3"
PATIO DOOR
MBR #2
11'-0" x 17'-10"
MBR #1
12'-6" x 18'-6"
MB
W.I. CLOS.
D
DN.
W/D
L.C.
SKYLT.
SKYLIT STUDIO
15'-6" x 7'-4" & 10'-6"
I UPPER LEVEL
ROOF TERR
12'-6" x 6'-0"
PATIO DOOR
VENT SKYLT.
SLOPED CLG.
8'-6" CLG.
MBR #1
12'-6" x 18'-10"
MBR #2
11'-0" x 17'-11"
MB
WALK-IN CLOS.
L.C.
DN
D
W
SKYLIT STUDIO
18'-4" x 7'-4" & 13'-6"
I1 UPPER LEVEL
BALC.
12'-6" x 6'-0"
PATIO DOOR
DR
11'-2" x 14'-8"
LR
12'-6" x 31'-6"
KIT
11'-0" x 10'-6"
P
DW
P.R.
UP
WALK-IN CLOS.
I, I1 LOWER LEVEL

#6



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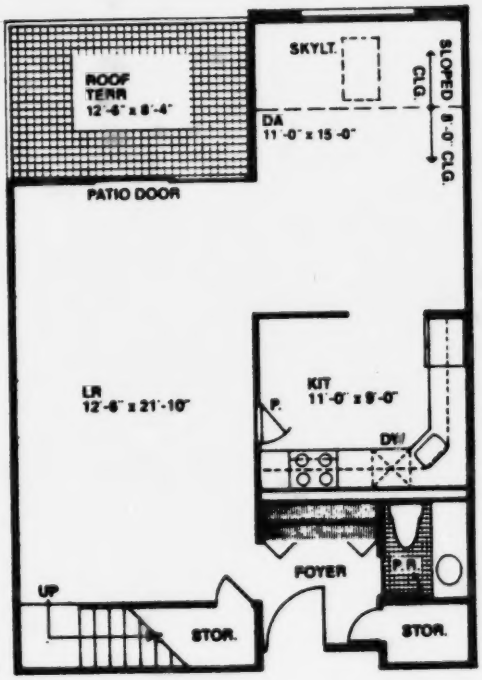

LOWER LEVEL

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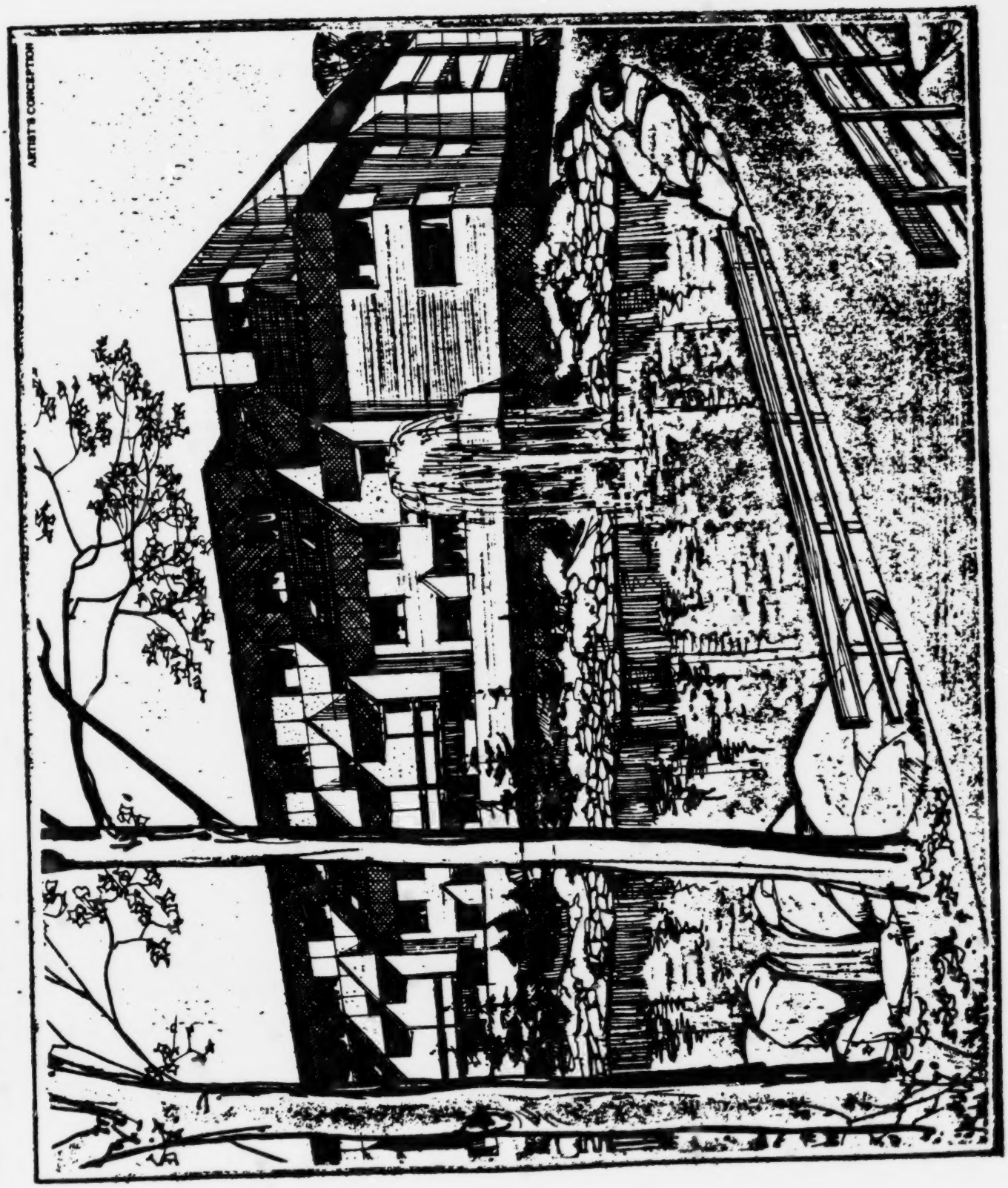


10(ii) PROJECT NAME:	Boatyard
PROJECT ADDRESS:	Caroll Street, City Island Bronx, New York
OWNER'S NAME & ADDRESS:	Boatyard Associates 255 Glenville Road Greenwich, Conn. 06830
DEVELOPER/GENERAL CONTRACTOR NAME AND ADDRESS:	Elite Associates (G.M.) 29 W. Marie Street Hicksville, New York 11801
ARCHITECTS NAME & ADDRESS:	William Milo Barnum Associates 255 Glenville Road, Greenwich, Conn. 06830
TYPE OF UNITS:	Condominium
NUMBER OF UNITS:	70
NUMBER OF BUILDINGS:	11
TOTAL LIVING AREA:	102,240 square feet
SITE AREA:	155,600 square feet
NUMBER OF STORIES:	3
LIGHT METAL FRAMING ITEMS INCLUDE:	Total L.M.F. structural system including all exterior walls, bearing interior walls, floor joists and roof rafters.
LIGHT METAL FRAMING PRICE:	Cost Plus (current)
MAN HOUR SUMMARY:	19/20/82 Shop - 3,128 m.h. Field -23,455 m.h.

The Boatyard

The Boatyard development is located in the extreme northern portion of N.Y.C. proper, on a small resort island called City Island. The project consists of approx. 70 condominium units built to date for a luxury retreat condominium market.

The units are configured along the shore of a mixed industrial and recreational marina site.

Unit configurations vary from approx. 1350 sq. ft. to 1590 sq. ft. Units also are comprised of single storey floor plans and 2 storey floor plans.

The buildings are in a tight configuration on 3.5 acre site in groupings around common facilities and underground parking. A strong maritime architectural theme has been adopted for the project and the result is an aesthetically pleasing turn of the century motif. The traditional appearance and massing of the building belies the fact that they are built with steel stud construction. The building configurations are relatively simple and box like in 3 storey configurations. However, the framing and structural systems are complicated by some long span requirements in the unit layouts. This means that in some areas additional structural steel has been used to augment the capabilities of built up rolled joist beams.

The project, when visited, was approx. 1/3 complete with model suites open for inspection and other buildings at various stages of completion.

The project, as undertaken by the light weight framing contractor, was a cost plus job and thus some of the costing is difficult to apply to other projects. The job also has a higher than normal component of on site construction rather than panelization due to the need for quick completion of the first 1/3 of the building.

The structural systems are comprised of load bearing steel stud interior and exterior walls with cold rolled formed joists as the principal floor component. Floor construction varies with separating floors from unit to unit in concrete and steel pan with interior floors contained within 2 storey units of plywood construction. It is worth noted that the cold rolled structural elements of this project are prime painted rather than galvanized steel members due to the source of supply. The contractor's experience with galvanized and painted product is that although painted steel represents a

Boatyard (continued)

slightly lower purchase price, the requirement for priming and painting of welds, etc., during construction, does not result in a cost savings over galvanized steel. Galvanized steel also to many clients represents a better product in terms of long life resistance to rusting.

Cost estimates for the units completed for the project are approx. $5.73 on a cost plus basis. This squ. ft. cost represents a cost which appears to be a mid range of sq. ft. costs for light weight metal buildings.

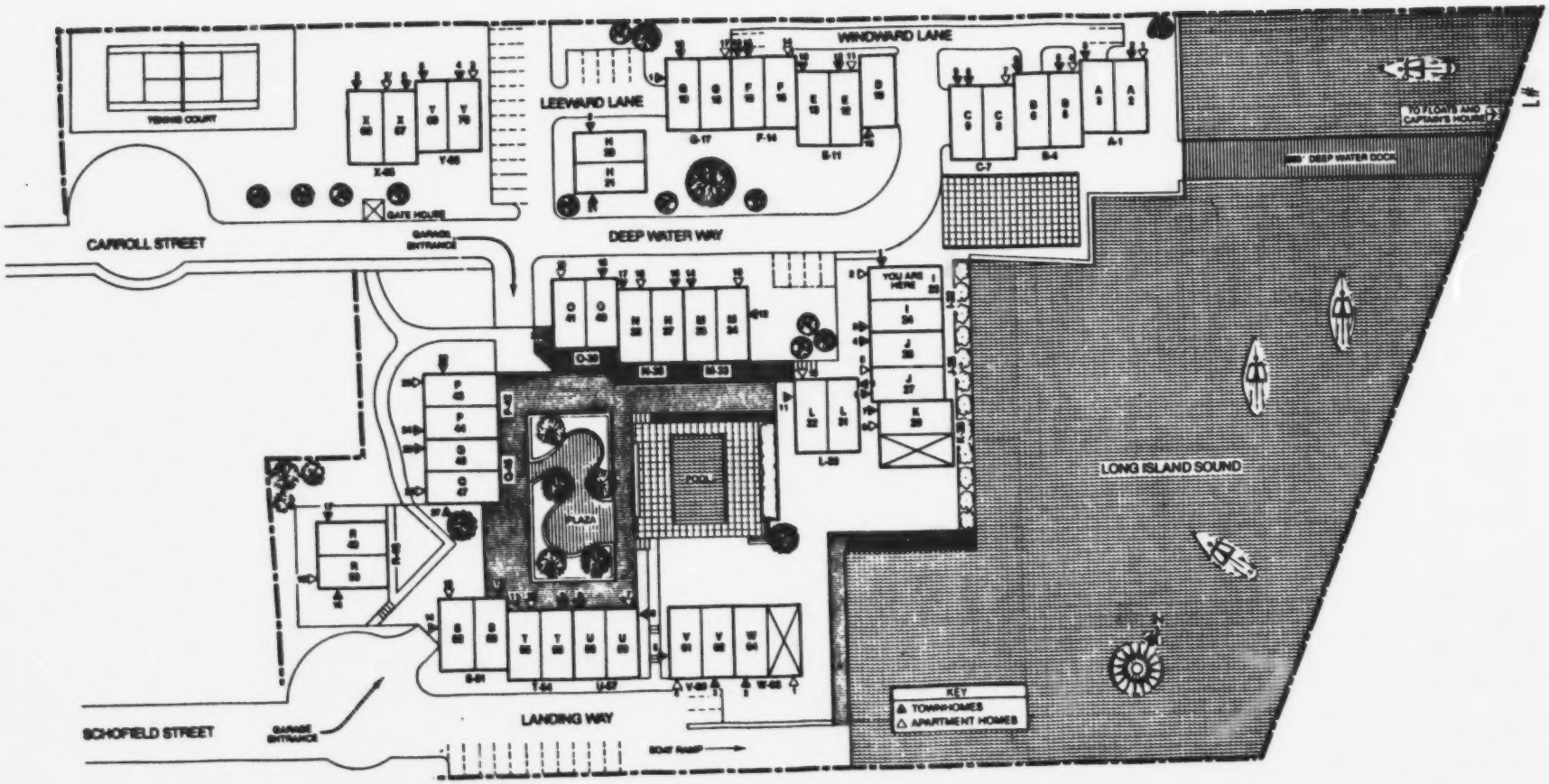
From the conversations with both the development company and their sales personnel, it is interesting to note that their experience has been of rapid acceptance by the potential purchasers of steel stud construction. It is shown in their brochure, work and also with their descriptions during showings of the units, that the buildings are built of steel stud construction, and that this represents a longer life and higher quality to the purchaser. It is also worth noting that acoustic problems are not raised by the potential purchaser and that the "solid characteristics" of masonry construction are not compared to this light dry walled method. The initial choice of using light weight metal framing for this project was directed from the developers group, and in particular one member from that group, who is an architect.

SUMMARY

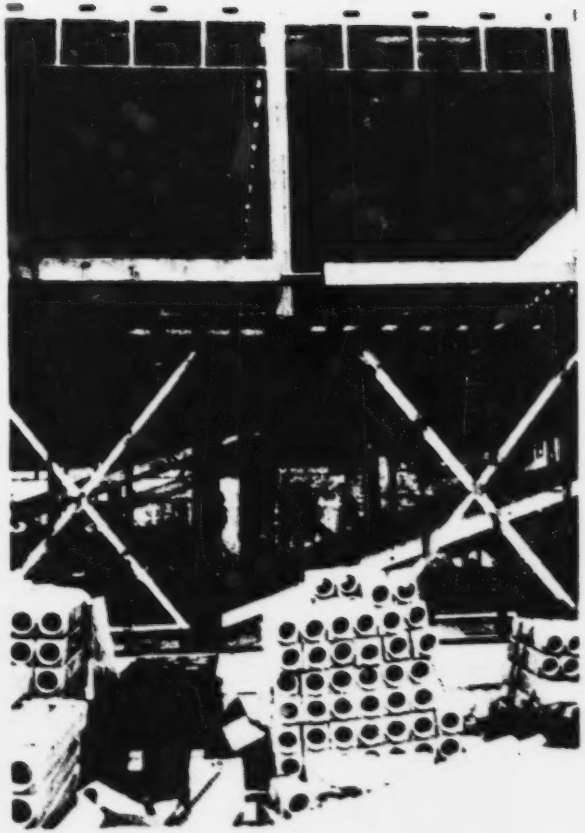
- LMF in its substitution for conventional wood framing is capable of reproducing conventional forms, massing and aesthetics.
- cost savings may not be realized in substituting painted material for galvanized metal due to the need for painting and priming at various stages of manufacturing.
- costs of $5.73/sq. ft. for this project demonstrate the average costs predicted in the example costing given. This may be attributed to its regular configuration and repeated form.

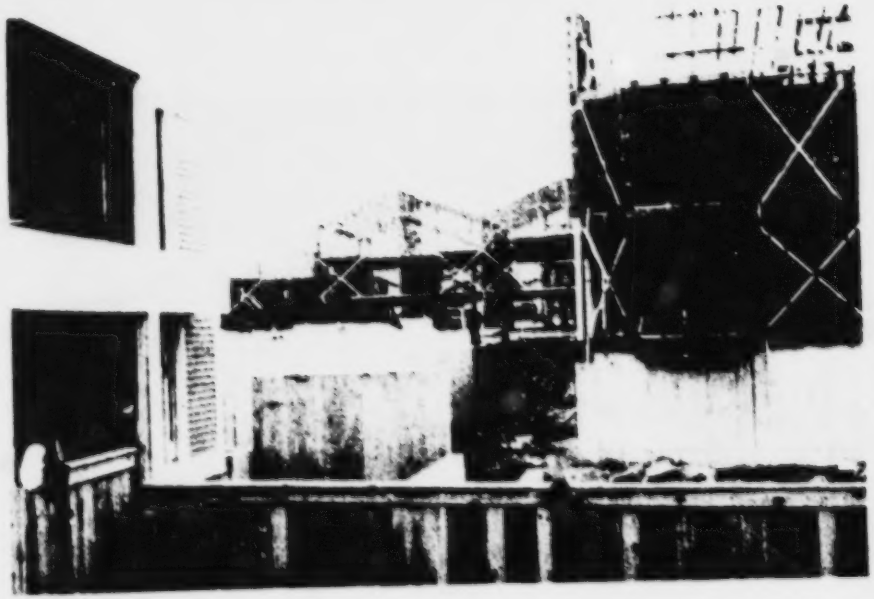
Illustrations, Boatyard

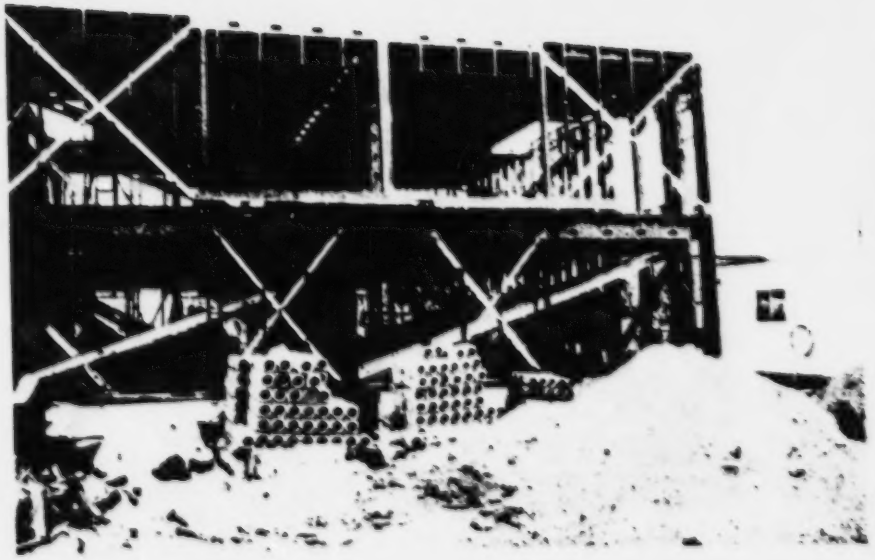
#1 - Site plan
#2-10 - Photos of building under construction
#11, 12 - Floor plans
#13 - Rendering

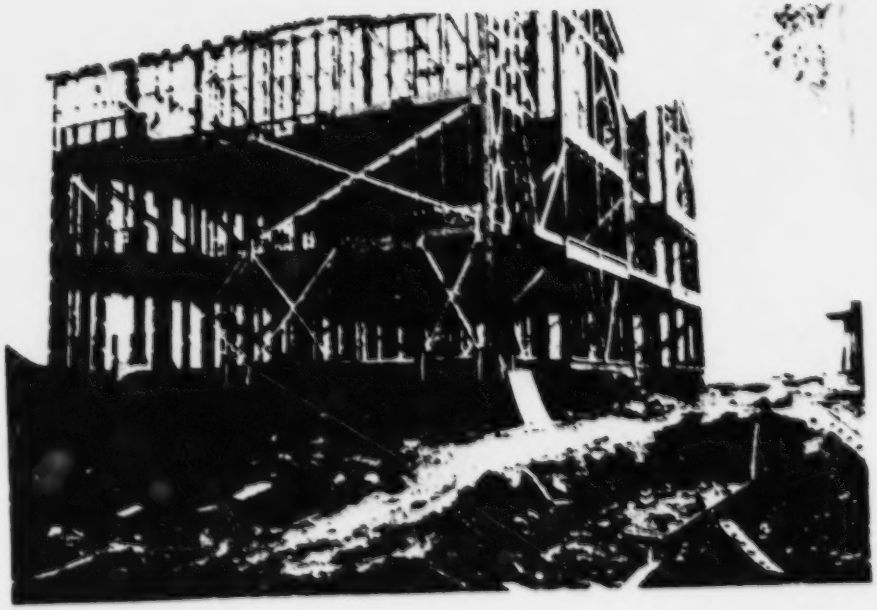

WINDWARD LANE
LEEWARD LANE
TENNIS COURT
GATE HOUSE
CARROLL STREET
GARAGE ENTRANCE
DEEP WATER WAY
YOU ARE HERE
POOL
PLAZA
LONG ISLAND SOUND
DEEP WATER DOCK
SCHOFIELD STREET
GARAGE ENTRANCE
LANDING WAY
BOAT RAMP
KEY
TOWNHOMES
APARTMENT HOMES

#2, 3 & 4

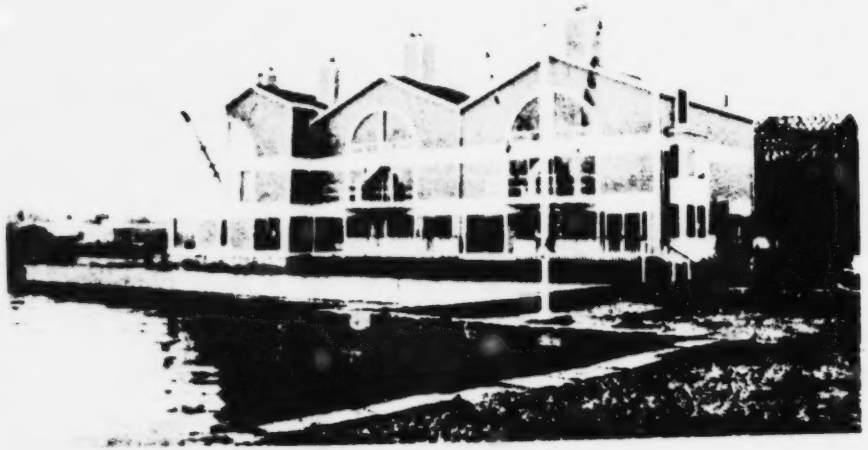








#8, 9 & 10



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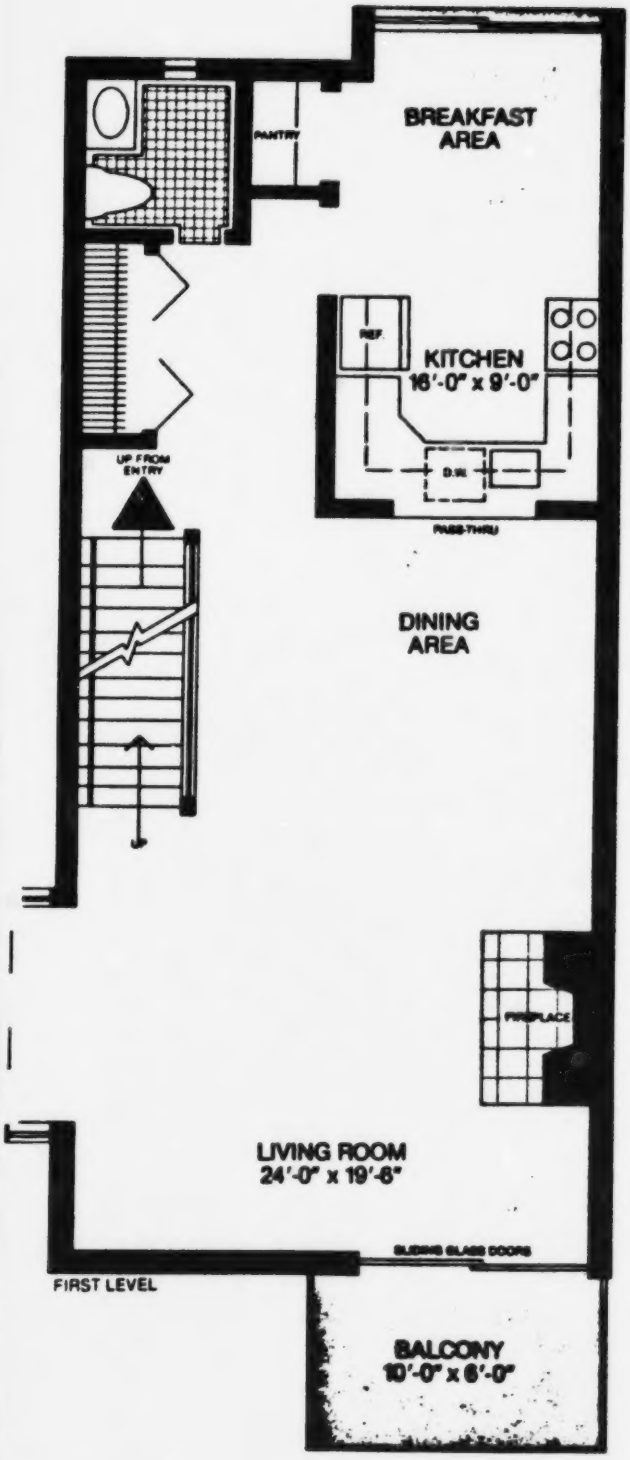
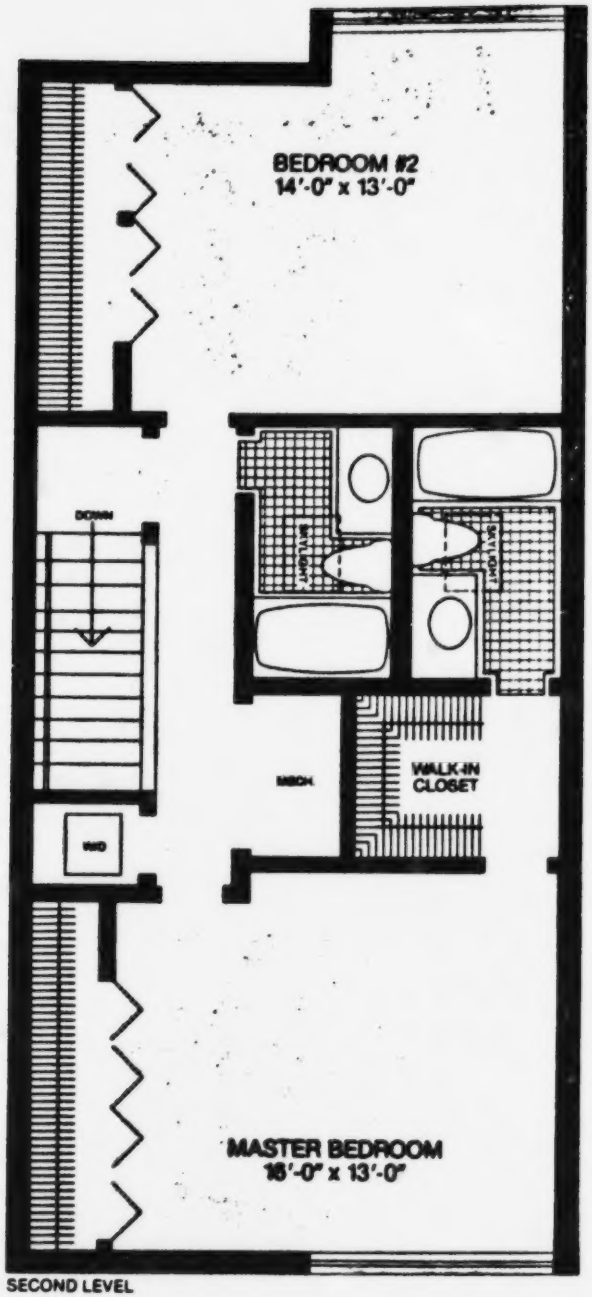
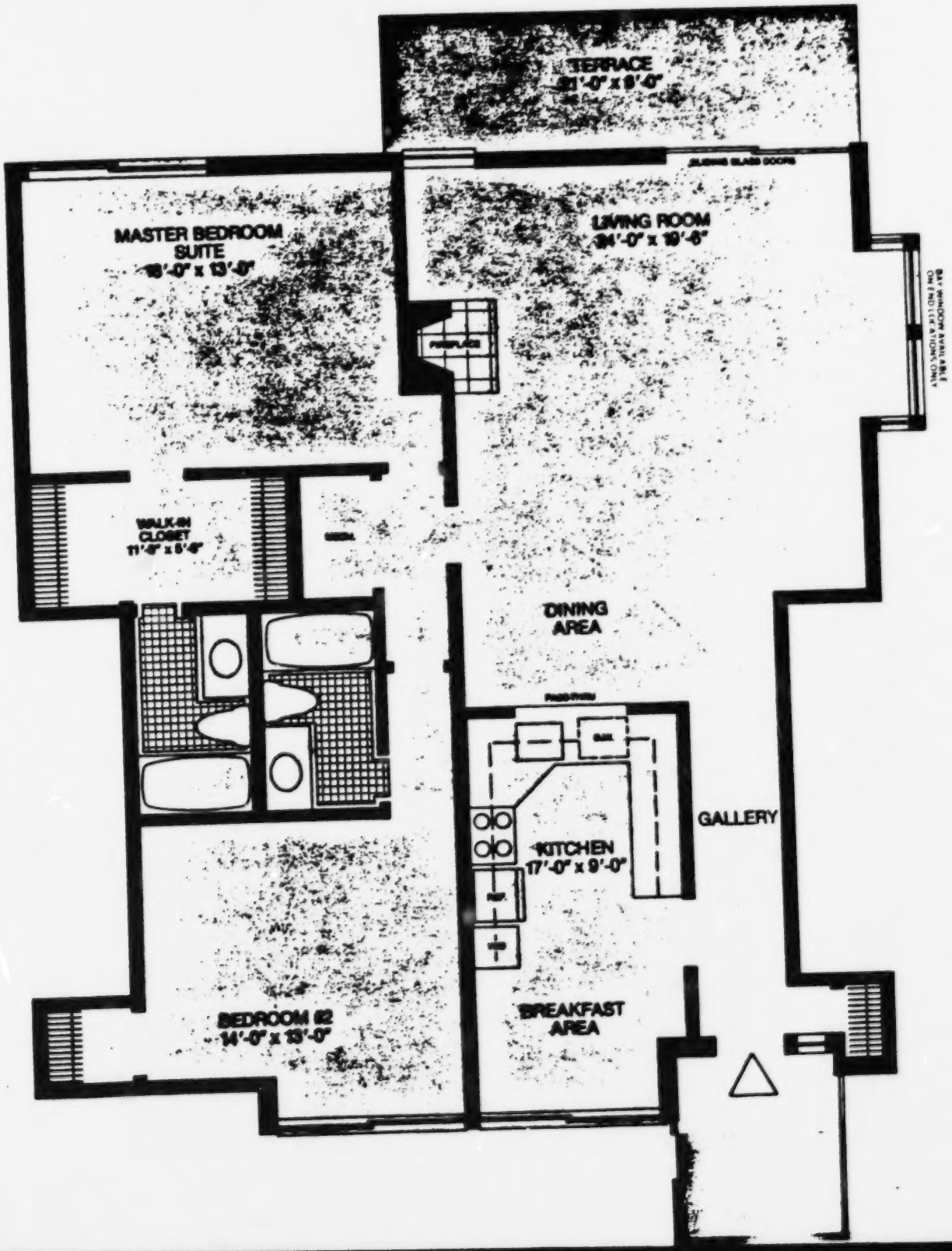


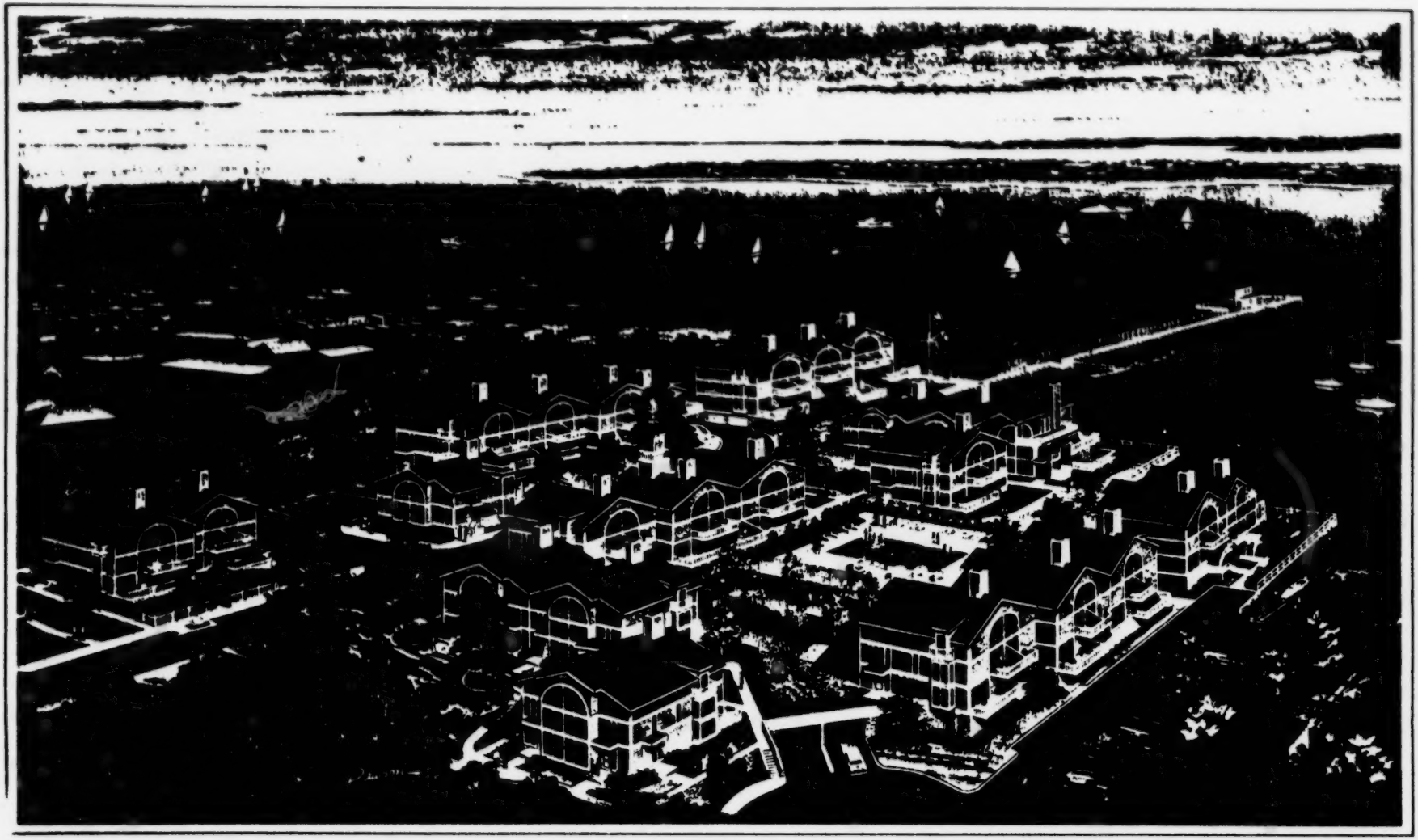
FIRST LEVEL



SECOND LEVEL

#12


TERRACE
21'-0" x 9'-0"
SLIDING GLASS DOORS
MASTER BEDROOM SUITE
18'-0" x 13'-0"
LIVING ROOM
24'-0" x 19'-6"
FIREPLACE
BAY WINDOW AVAILABLE ON FINDLEY ELEVATIONS ONLY
WALK-IN CLOSET
11'-4" x 5'-4"
LINEN
DINING AREA
PASS-THRU
SINK
GALLERY
KITCHEN
17'-0" x 9'-0"
REF.
DW
BEDROOM #2
14'-0" x 13'-0"
BREAKFAST AREA



Artist's rendering

10(iii)	PROJECT NAME:	Bronxville Glen
	PROJECT ADDRESS:	Midland Ave. Bronxville, N.Y.
	OWNER'S NAME & ADDRESS:	Cadillac Fairview, Inc. 2050 Central Ave. Fort Lee, N.Y. 07024
	DEVELOPER/GENERAL CONTRACTORS NAME & ADDRESS:	Same as above
	ARCHITECTS NAME & ADDRESS:	Gismondi & Arnold, Architects 235 Mamaroneck Ave. White Plains, N.Y. 10605
	TYPE OF UNITS:	Condominiums
	NUMBER OF UNITS:	108
	NUMBER OF BUILDINGS:	5
	TOTAL LIVING AREA:	162,283
	SITE AREA:	N.S.
	NUMBER OF STORIES:	3
	LIGHT METAL FRAMING ITEMS INCLUDED:	Total L.M.F. Structural system including all exterior wall, interior bearing walls, floor joists and roof rafters
	LIGHT METAL FRAMING PRICE	$750,000 (start June 1980)

Bronxville Glen

Bronxville Glen is a development of approximately 76 condominium units, averaging 550 sq. ft. per unit. The units consist of one storey,one and two bedroom units, and two storey,one and two bedroom units.

Once again, the construction of these units is a mixture of light weight metal framing and interior with some masonry bearing walls. This project was of interest from the point of view that it consists of typical townhouse units but was also of interest due to the complex nature of its unit arrangement. The project was approximately 1/2 complete and again has suffered from a slow sales program, but was proceeding once again with all haste.

In conversation with the sales staff, it revealed a general acceptance by the public of this type of construction, and in fact was not a negative issue in the acceptance of these units. It is interesting to note that the first point in the sales brochure is "brick, veneer, steel and reinforced concrete construction", implying to a purchaser that these units are of a high quality. The developer of these units is Cadillac Fairview Inc., and also emphasized in the sales brochure were the high insulation and thermal design of the project.

These units varied from completed and occupied to those still under construction. In the units still under construction, and in consideration with the complicated floor plans and section plans to the units, it is interesting to note that some problems were evident between the co-ordination of the mechanical systems and the light weight metal framing. It was apparent in this project and inferred in other projects visited, that the co-ordination of the mechanical design and structural design is of particular importance in light weight metal framing.

In many instances, beams or plates had been cut by mechanical sub-trades in order to accommodate their particular requirements. In addition, some mechanical system distribution plans would seem to have been adopted from other forms of construction, and made to fit light weight metal framing.

It is the author's opinion that there are dramatic differences between light weight metal framing and other construction types that require a modified approach to mechanical systems.

Once again in this project, the siting and distribution of units was quite pleasing, and due to a certain extent in the freedom afforded by this type of construction. As in the Glenpoint, and in some of the other projects visited, the climatic differences between the N.Y.C. area and Canada afford greater freedom in unit design and detailing. However, light weight metal framing and the ability to cover the exterior with a variety of panel or screening systems should allow freedom in design and accomplish a better project result.

SUMMARY

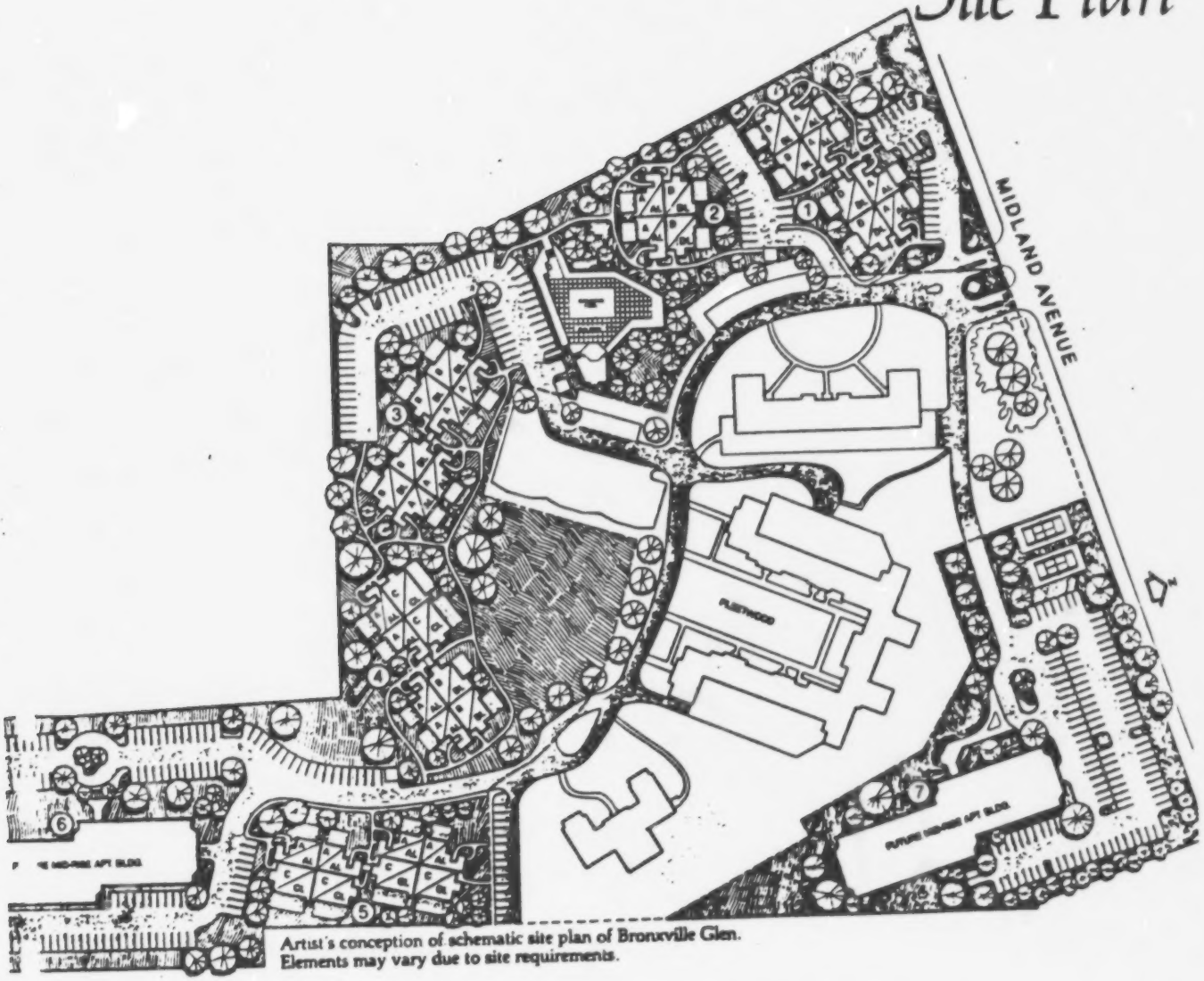
- attention in design and construction must be given to the intergration of mechanical systems and LMF.
- LMF may offer some advantages to the designer in accommodating variations in unit designs in such elements as split-levels, lofts, mezzanines, and balcony construction.

Illustrations, Bronxville Glen

#1 - Site Plan
#2-4 - Floor Plans
#5 - Rendering

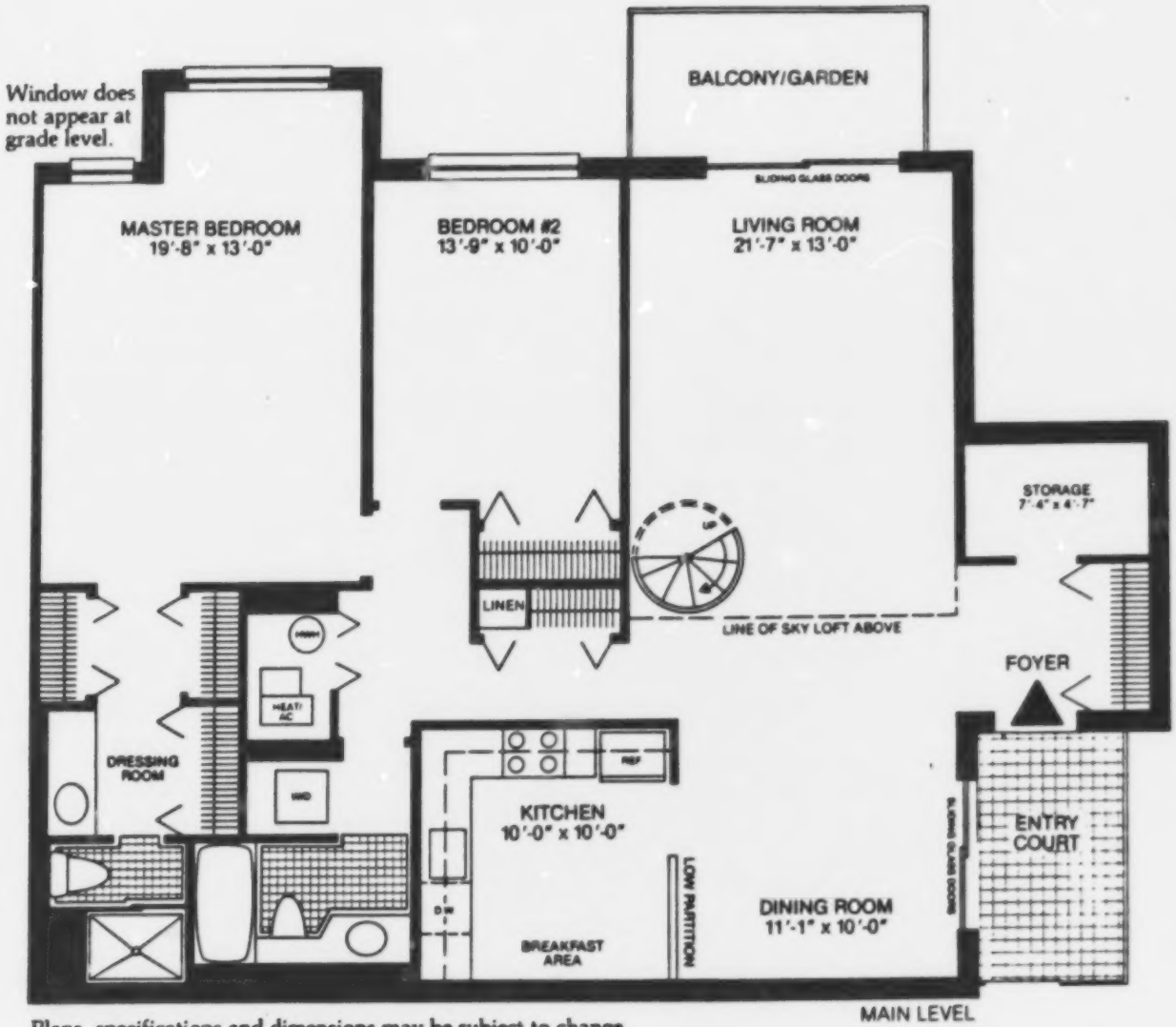
#1

Site Plan



Artist's conception of schematic site plan of Bronxville Glen.
Elements may vary due to site requirements.

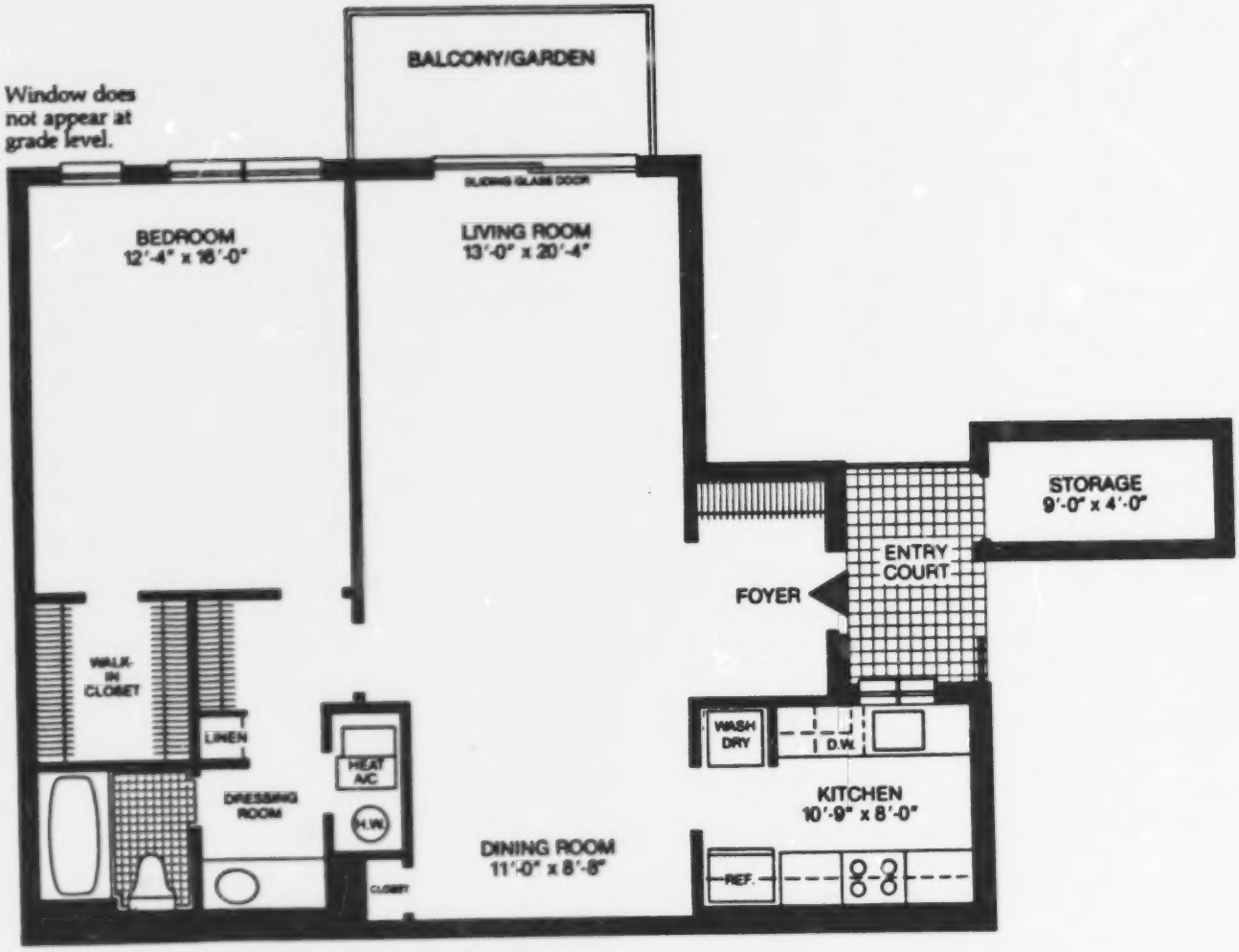
#2



MAIN LEVEL

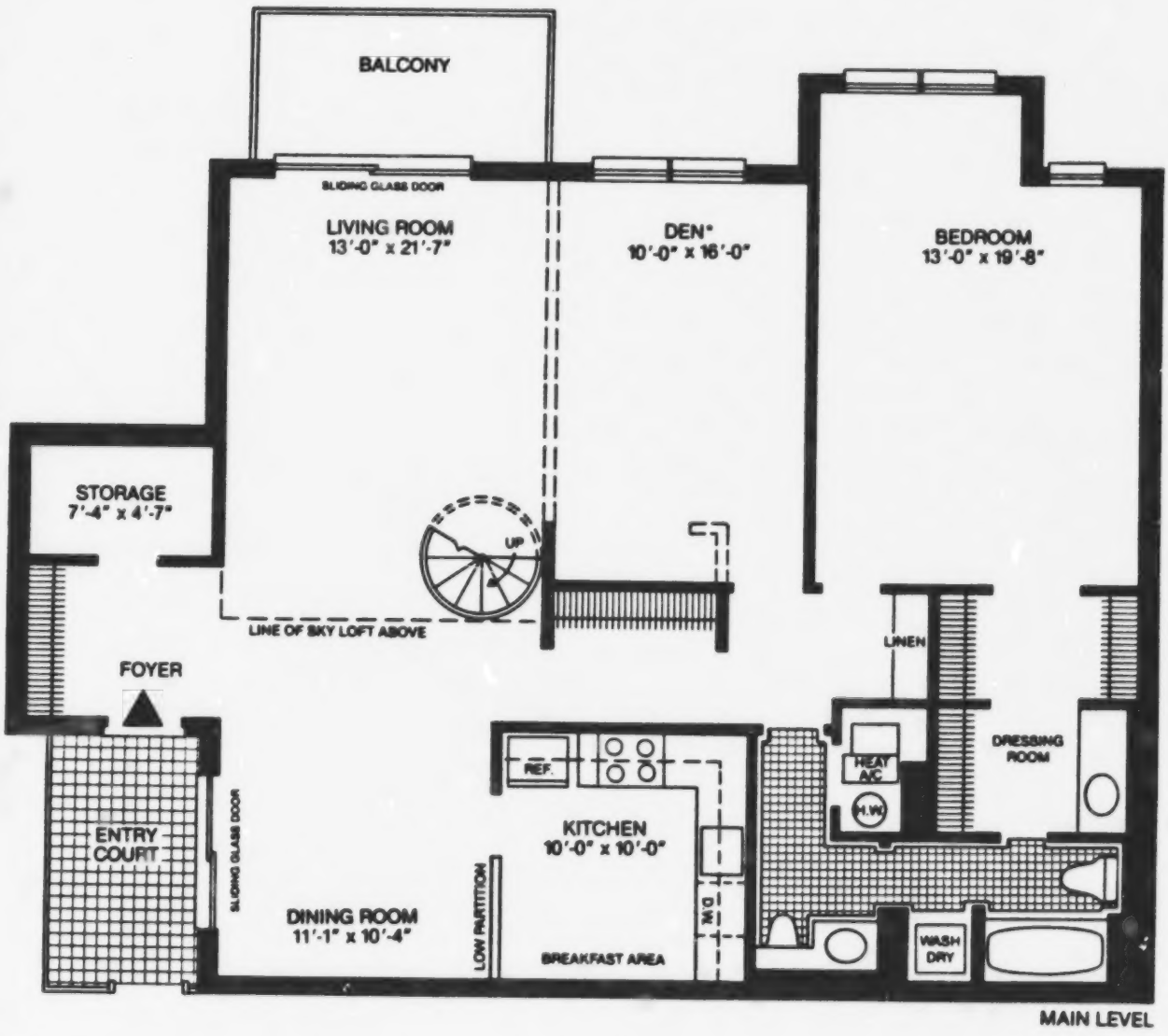
Plans, specifications and dimensions may be subject to change due to marketing and construction considerations.

#3



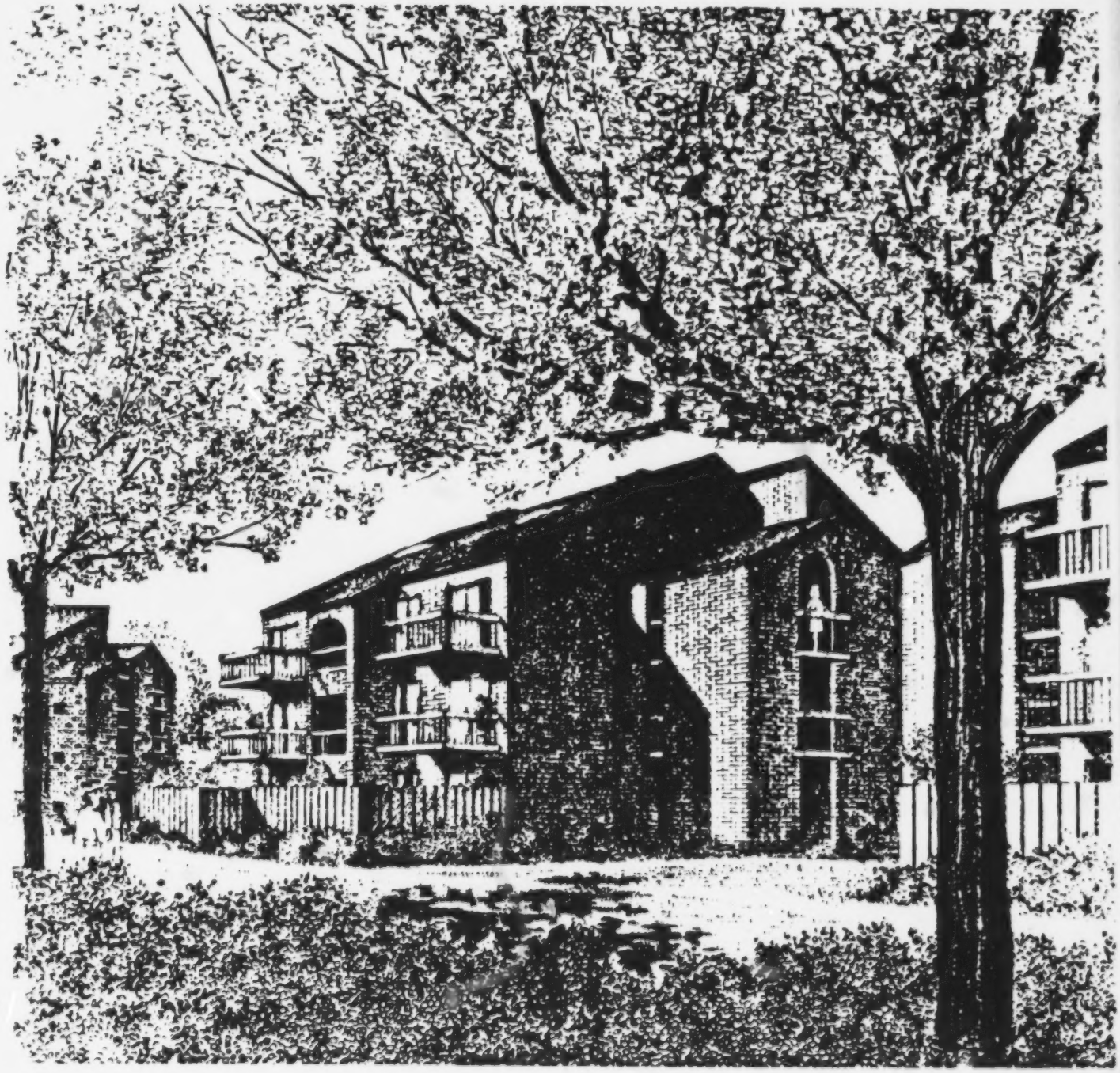
Plans, specifications and dimensions may be subject to change due to marketing and construction conditions.

#4


BALCONY
SLIDING GLASS DOOR
LIVING ROOM
13'-0" x 21'-7"
DEN*
10'-0" x 16'-0"
BEDROOM
13'-0" x 19'-8"
STORAGE
7'-4" x 4'-7"
UP
LINE OF SKY LOFT ABOVE
LINEN
FOYER
REF.
HEAT A/C
H.W.
DRESSING ROOM
ENTRY COURT
SLIDING GLASS DOOR
KITCHEN
10'-0" x 10'-0"
DW
LOW PARTITION
DINING ROOM
11'-1" x 10'-4"
BREAKFAST AREA
WASH DRY

MAIN LEVEL

#5



10(iv)

PROJECT NAME:	Glenpointe Condominiums
PROJECT ADDRESS:	Teaneck, New Jersey
OWNER'S NAME & ADDRESS:	Glenpoint Associates P.O. Box 2187, South Hackensack, N.J. 07606
DEVELOPER/GENERAL CONTRACTOR NAME & ADDRESS:	Alfred Sanzari Enterprises Address same as above
ARCHITECTS NAME & ADDRESS:	Pellaton & Chapman, Architects 79 Croton Avenue, Ossining, N.Y. 10562
TYPE OF UNITS:	Condominiums
NUMBER OF UNITS:	171
NUMBER OF BUILDINGS:	12
TOTAL LIVING AREA:	379,359 sq. ft.
SITE AREA:	630,357 sq. ft.
NUMBER OF STORIES:	4
LIGHT METAL FRAMING ITEMS INCLUDED:	Total L.M.F. structural system including all exterior walls, interior bearing partitions, floor joists and roof patterns.
LIGHT METAL FRAMING PRICE:	$2,900,000

COST ESTIMATE BREAKDOWN:

Engineering and S.D.	$ 39,000
material	990,000
panel fab.	840,000
delivery	94,000
erection	712,296
mobilization	45,000
plywood, balconies, chimney	140,000

MAN HOUR SUMMARY: Erection (51%) - 19,869 m.h.

GENERAL COMMENTS:

	Total	Per square foot
Material supply	990,000	2.60
fabrication	840,000	2.21
shipping	94,000	.24
Engineering & shop drawing	39,000	.10
erection	712,296	1.88
erection man hours (based on 51% completion)	38,958	18.28/man hour

Glenpoint Condominiums

This project consists of condominium units designed as a residential portion of a commercial development. Located in New Jersey with easy access to central N.Y.C., the development is planned as "luxury condominium", with a total unit number of 171 in twelve buildings, at final completion.

At the time of the author's visit to the site, approximately 1/2 of the project was complete, and approximately 1/4 sold and occupied. The project was delayed at that time with contractual disputes and with a slow acceptance by the public for its offering.

These units represent a demonstration of luxury condominium use of light metal framing, and demonstrate some of the complexities possible with its design.

Average unit sizes for this development are approx. 2,200 sq. ft. The buildings are 4 storey buildings with 3 storey living units above garage area. The buildings are in small groupings of 4 units in separate attached buildings, and 8 - 12 unit row configurations. The exterior configurations, roof lines and entrances have produced a complicated floor plan for the projects.

The buildings demonstrate some of the inequalities of light weight metal framing, such as the light loading required for these projects. A substantial savings and reason for use of light weight metal framing was due to the ground conditions on the site. The site had poor ground conditions consisting of land fill to a depth of 8 or 10 feet. A light loading required for this type of construction produced a savings in foundation cost.

Originally designed for in situ construction of light weight metal framing, the project was changed to off site prefabrication, when an accelerated construction schedule was demanded in anticipation of first sales of condominium units. This increased the sq. ft. cost for the light weight metal framing, but assisted the developer in producing the units for sale.

The buildings were originally designed for concrete floor construction. However, at the request of the contractor, this was changed to a plywood deck system above parking level. It is interesting to note that in the opinion of the light weight metal framing contractor, this did not result in any saving to the framing contract, and the re-

necessitated some additional expenditures. All roof construction is light weight metal framing with plywood decking and shingles, and in addition the light weight metal framing contract included an additional chimney, ducts, balconies, and stairwells required.

The cost estimates which are contained in the breakdown demonstrate the fairly high cost in terms of prefabrication and material supply, as compared against other jobs. The total sq. ft. cost of $7.64 also represents a relatively high sq. ft. cost as compared to other projects. However, upon closer inspection, this cost may be due to the partially complete state of the entire contract, and therefore included mobilization, and first costs such as engineering, which, when extended over the entire job, would bring the average sq. ft. cost down slightly.

This project demonstrated some of the versatility of light weight metal framing, and some of the complex patterns which can be used in each project. The siting and density achieved in the project is very pleasing and when consideration is given to the depressed condominium in this region, it has been a success from the sale point of view. Again, a level of resistance was experienced in the sales program to the use of light weight metal framing.

SUMMARY

- the average cost of $7.64/square foot attributed to this project is consistant with the +20% range of costs from those shown in the typical example.
- it is interesting to note that in the contractors opinion there was not a cost savings in using plywood floor systems in place of steel deck and concrete.
- additional costs for projects with a majority of panels manufactured by sub suppliers in order to achieve accelerated construction schedules may be assumed.
- care should be taken in the re-design of projects to LMF systems in order that all economies may be achieved.

10(v) PROJECT NAME: Bushwick II - Community Development Plan

PROJECT ADDRESS: Phase I - Brooklyn, New York

OWNER'S NAME & ADDRESS: N.Y.C. Housing Authority

DEVELOPER/GENERAL CONTRACTOR NAME & ADDRESS: Urban Universal Structures
1088 Hancock Street
Brooklyn, N.Y. 11221

ARCHITECTS NAME & ADDRESS: Tudda, Scherer, Zborowski, P.C.
210 E 52nd Street
N.Y.C., New York

TYPE OF UNITS: Low income housing

NUMBER OF UNITS: 600

NUMBER OF BUILDINGS: 50

TOTAL LIVING AREA: 615,600 sq. ft.

SITE AREA: 834,233 sq. ft.

NUMBER OF STORIES: 3

LIGHT METAL FRAMING ITEMS INCLUDED: Total L.M.F. structural system including all exterior walls, bearing interior walls, floor joists and roof trusses

LIGHT METAL FRAMING PRICE: Cost plus on erection (current)

COST ESTIMATE BREAKDOWN:

Material	$ 30,000
wall panel and truss fab.	7,500/bldg.
floor panel fab.	6,000/bldg.
erection	25,000
Total	3,425,000

MAN HOUR SUMMARY: Erection estimate - 920 m.h./building

GENERAL COMMENTS:

	Totals	Per Square Foot
Material supply	30,000	2.43
fabrication	13,500	1.09
shipping		
engineering and shop drawing		
erection	25,000	2.03
erection man hours	920 m.h.	27.17/m.h.

Bushwick II Community Development Plan

Phase I:

This project will result in a total of 600 units constructed by a private developer for the N.Y.C. Housing Authority. It is located on various in-fill sites in the south Bronx area of N.Y.C. The present area is quaintly described as an urban renewal neighbourhood, where the present housing stock has suffered through neglect, arson, and other forms of abuse.

This example project represents to the author perhaps the best example of light weight metal framing that he visited during this time in the New York area. The history of the project has been that a developer engaged a consultant to provide buildings in light metal framing, for this project has a demonstration of its capabilities to the N.Y. Housing Authority, and in order to solve some on site problems he had anticipated in terms of theft, destruction of partially completed buildings, and system production capabilities. The project was originally designed by the Tate consultant for complete onsite construction methods utilizing screw connections for all pieces of the project. Numerous difficulties were experienced during the first few buildings, compounded by the death of a consultant at this time. The developer then suffered a collapse of 2 buildings due to incomplete temporary framing. The project was then re-examined by the N.Y.C. Housing Authority, andre-tendered to R.H. Kilmer and Ass. Construction methods were then changed with an emphasis on off-site panelization of floors and walls, as well as a complete welded connection for all assemblies.

The project, when the author visited it, had a number of completed buildings, a number of partially complete on site constructed buildings, and a number of panelized buildings in various stages of completion.

Each building is approx. 12,000 sq. ft. with the total project area, when completed, being 615,000 sq. ft. The total number of units is 600 units in 50 buildings. Each building is comprised of 12 units varying in size from 1 bedroom to 3 bedroom units in 3 storey configurations.

The unique qualities which this project exhibits are a very efficient and tight walk up style apartment building with repeated buildings allowing maximum economy in panelization and erection to be achieved. The project at the time that the author visited it, had not moved in to high production due to the short time of which the 2nd contractor had been on the job. At that time difficulties were being experienced by the 2nd contractor, in supply of sufficient numbers of floor panels by the supplier in the Boston area. However, the construction activity on the site proved to have other interesting aspects. At the time of the author's visit in September, the particular buildings shown in the accompanying photographs was partially complete with wall panels and floor panels being erected on the day of the visit. Because of the shortage of floor panels, a small production facility had been set up on the job site to allow fabrication of floor panels at the site. Demonstrated during this visit were the erection and prefabrication methods employed on other projects visited during the trip to New York.

Assembly of floor panels consisted of a job separated into the following tasks: pre-cut floor joist lengths had been delivered to the site as well as pre-cut joist material for bridging and bracing. On site joist lengths were adjusted for stair openings and other atypical portions of the structural plan. A small skill saw with steel cutting blade was used to cut the lengths by a single person into the required lengths for fabrication. These were then taken to a small open shed building where the joist lengths were welded into approx. 8 x 40' panel sections. Two semi-skilled welders were employed in this fabrication as well as one lead hand responsible for overseeing the production of the panels. Welding in this operation was done with 2 mink welders and the productivity rates quoted for this format operation were approx. 40 sq. ft. of panel /hour. This productivity rate compared favourably with the productivity rates in the contractors shop. Completed panels were then transported around the site by hand, requiring at most 3 people. Production of the panels had proceeded for some time, and during the author's visit, panels had been stacked alongside the foundation walls of the building. A 20 ton crane was used to lift wall panels into place on the building. The crew required to lift and fit the panels into the building were one crane operator, one lead hand to direct the lifting operation, and two labourers to position the panels into place.

As floor and wall panels were arranged in place a crew of four labourers tack screwed the panels and applied temporary bracing where required to position the units in their proper place. The next operation consisted of three welders who then applied arch welded jussup plates and stress plates where required to join and fix panels in their final position. The job was overseen by one superintendant on site at all times, and one representative of the company who rotated between various buildings. Erection time for a completed building was approx. 920 man hours. Due to the amount of fabrication which occurred on site and to some of the problems experienced at the beginning of this construction process, it is a contractor's opinion that the on site man hours were excessive. Complete erection of one of these buildings should take place with floors and walls panelized in approx. 7 days for the entire crew on site. The cost estimates for this project are approx. $5.56/sq. ft. This is slightly lower sq. ft. cost and represents a savings due to the simple configuration and repeated nature of the project.

All construction consists of galvanized metal studs and floor joists. Interior floors consist of light gage steel pan with concrete topping.

The simplicity of prefabrication in construction are well illustrated in this example. Advantages in light weight metal framing of quick construction erection times are also apparent, although a one and a half week construction time is shown for the erection of an entire project, with proper preparation of foundation slabs, and presence of all panels on the site, the actual erection of the panels and floors can take place in a couple of days. Additional bracing and final accessories would fill out the job site for a slightly longer period of time. From the point of view of materials, construction methods and construction time, light weight metal framing would seem to be ideally suited to this type of project.

SUMMARY

- this project represents the best example of the simplicity of design, fabrication and assembly.
- this project, at an average cost of $5.56/sq. ft., also represents an approximate average cost for the system.
- to problems experienced with previous attempts to use on site assembly with "screw" connections for the project should also be noted. This demonstrates the inherent advantages of welded connections.
- also demonstrated are the higher degree of sophistication by the contractor required for panelized construction.
- requirements for simple tooling and construction equipment are also demonstrated by this project.

Photos - Bushwick II

#1 & 2 - Site area in the South Bronx, N.Y.C.

3 & 4 - Units nearing completion. Clad in brick and metal siding, these are 12 unit walk-up buildings.

#5 - Material and cutting operation for the pre-fabrication of floor panels on the construction site.

#6 - The temporary sheds built on site for fabrication of the floor panels.

#7 - Operator and MIG welder in temporary shed.

#8 - Assembly of floor panels by one lead hand and two welders.

#9 & 10 - Stockpiling and transfer of floor panels from fabrication area to building.

#11 - Floor panel being positioned by crane and two labourers.

#12 - Positioning of floor panel and final welds being completed to wall panels by arc welder.

#14 - Labourer fixing temporary bracing to wall panel and steel deck.

#15 - Panel being welded into position and labourer temporarily fixing panels with a screw gun.

#16 & 17 - Labour crews fixing wall and floor panels.

#18 - The majority of site equipment required is shown here for the erection of the building - a 25 ton crane, site generators and arc welders, electric screw guns, levels, cutters, skill saws, etc.

Photo #1

Photo #2

Photo #3

Photo #4

Photo #5

Photo #6

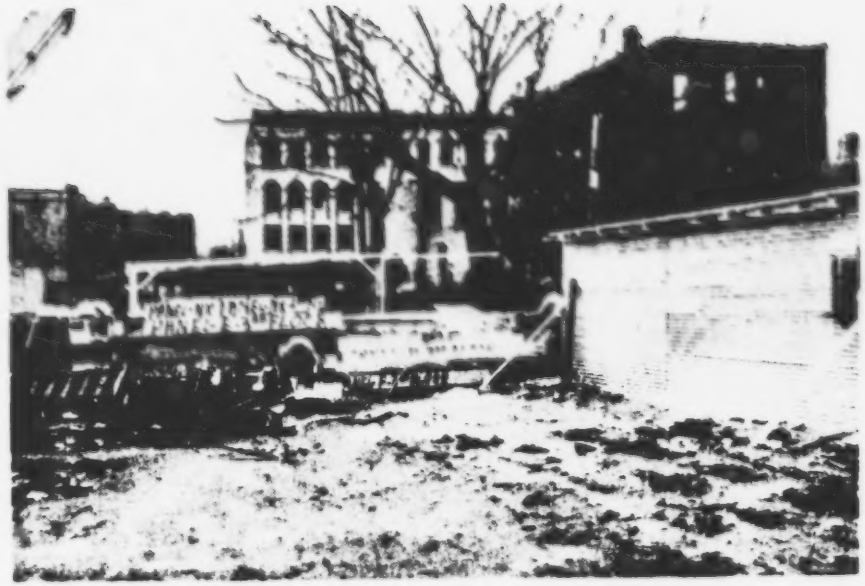


Photo #7

Photo #8 -

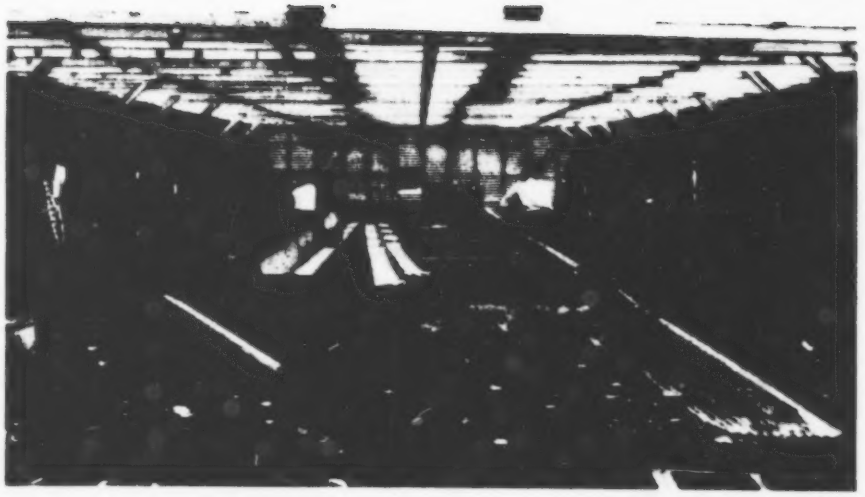


Photo #9

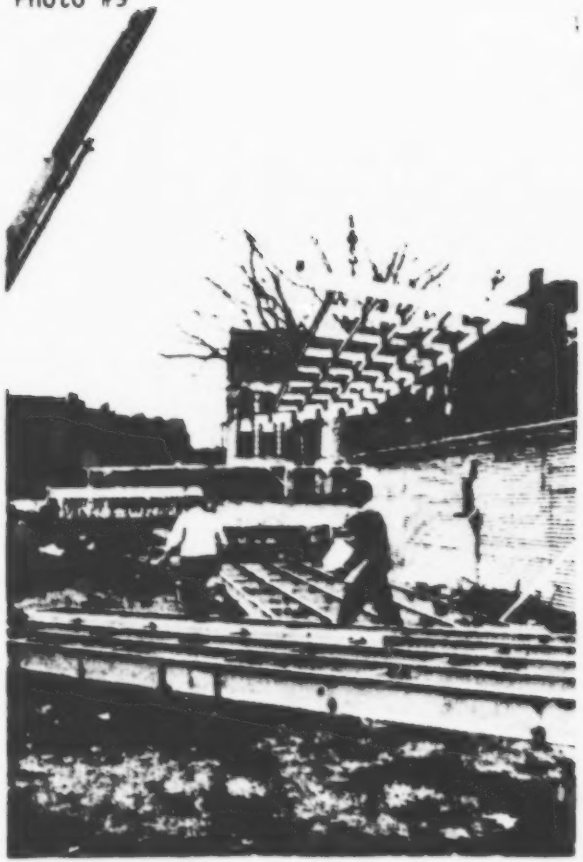


Photo #10

Photo #11

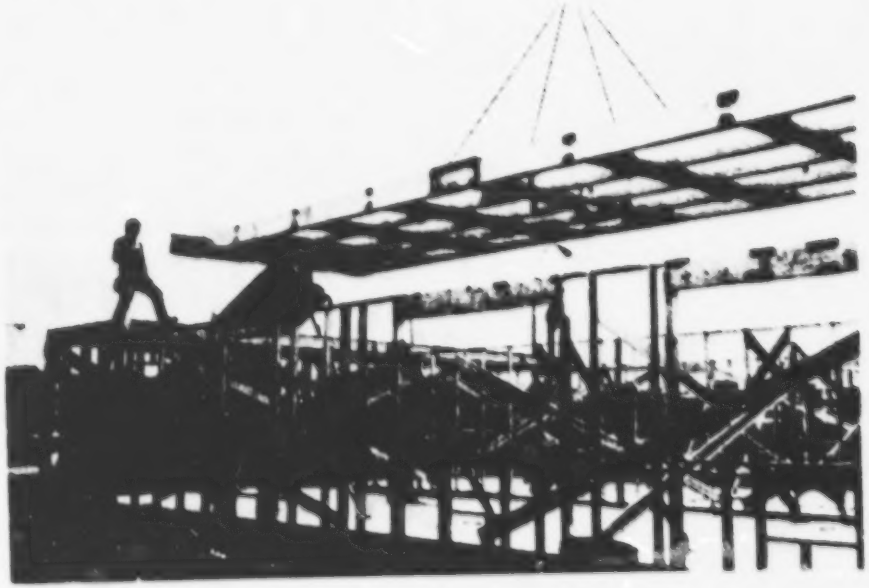


Photo #12

Photo #14

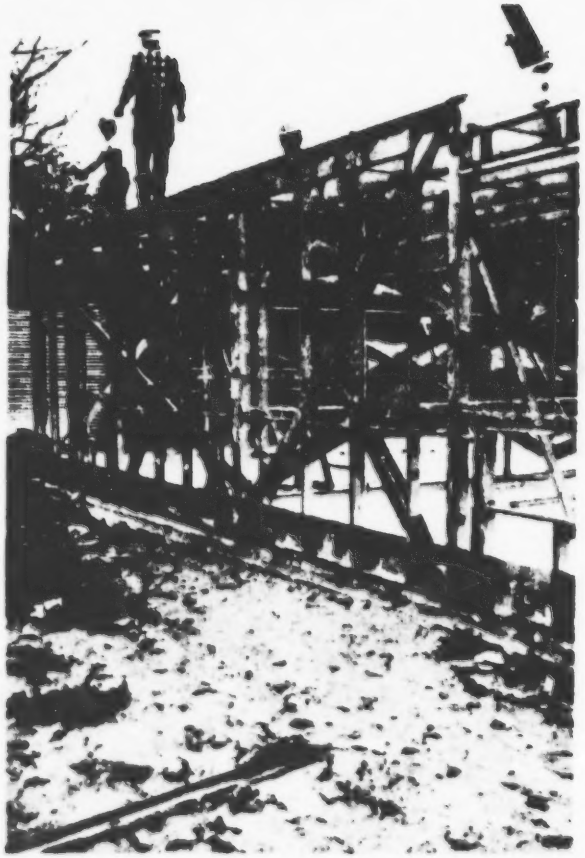


Photo #15

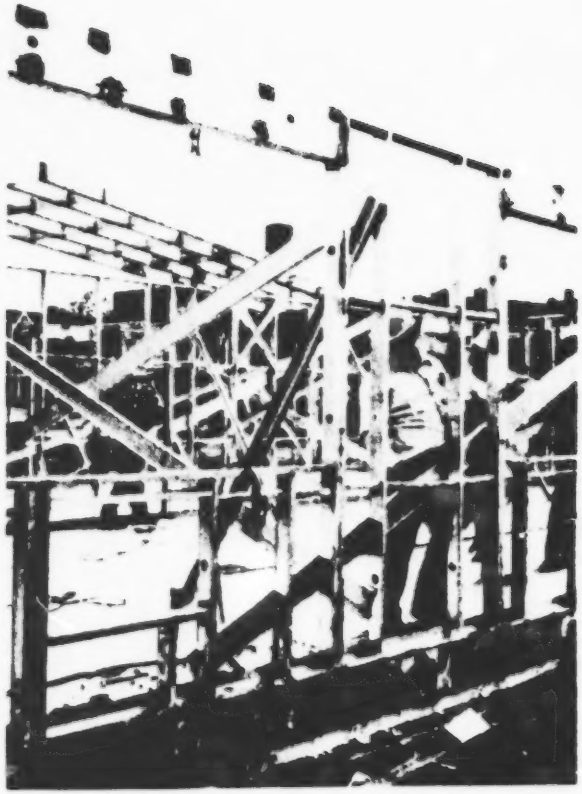


Photo #16

Photo #17

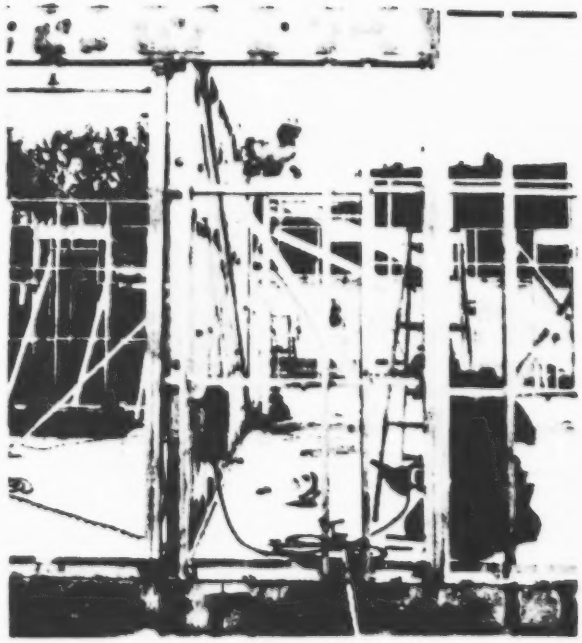
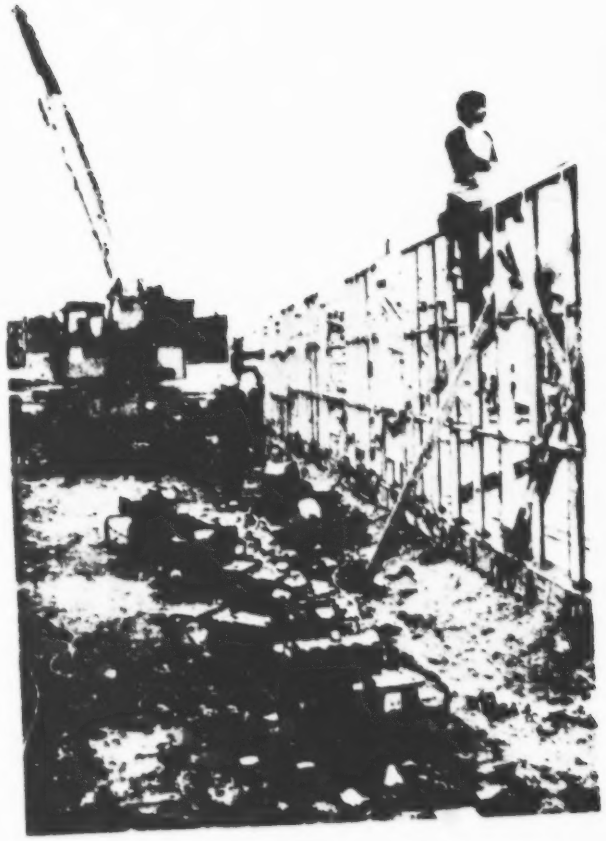


Photo #18



10(vi)

PROJECT NAME:	Scarsdale Woods
PROJECT ADDRESS:	Central Park Ave. Town of Greenburgh, N.Y.
OWNER'S NAME & ADDRESS:	500 Central Scarsdale Woods, Inc. 900 Midland Ave. Yonkers, N.Y. 10704
DEVELOPER/GENERAL CONTRACTOR NAME & ADDRESS:	Perbar Construction Corp. 900 Midland Ave. Yonkers, N.Y. 10704
ARCHITECTS NAME & ADDRESS:	Gismondi & Arnold, Architects, P.C. 235 Mamaroneck Ave. White Plains, N.Y. 10605
TYPE OF UNITS:	Condominiums
NUMBER OF UNITS:	76
NUMBER OF BUILDINGS:	4
TOTAL LIVING AREA:	117,845 sq. ft.
SITE AREA:	170,906 sq. ft.
NUMBER OF STORIES:	4
LIGHT METAL FRAMING ITEMS INCLUDED:	Floor joist system for first 3 floors with interior bearing walls, total L.M.F. system for 4th floor exterior walls, interior bearing walls and roof rafters.
LIGHT METAL FRAMING PRICE:	$218,000 (winter 1981-82)

PROJECT NAME:	Scarsdale Meadows
PROJECT ADDRESS:	Central Park Ave., Town of Greenburgh, N.Y.
OWNER'S NAME & ADDRESS:	555 Central Scarsdale Meadows Inc. 900 Midland Ave. Yonkers, N.Y. 10704
DEVELOPER/GENERAL CONTRACTOR NAME & ADDRESS:	Perbar Construction Corp. 900 Midland Ave. Yonkers, N.Y. 10704
ARCHITECTS NAME & ADDRESS:	Gismondi & Arnold, Architects P.C. 235 Mamaroneck Ave. White Plains, N.Y. 10605
TYPE OF UNITS:	Condominiums
NUMBER OF UNITS:	60
NUMBER OF BUILDINGS:	3
TOTAL LIVING AREA	80,016 sq. ft.
SITE AREA:	131,602 sq. ft.
NUMBER OF STORIES:	3
LIGHT METAL FRAMING ITEMS INCLUDED:	Floor joists and roof rafters, all exterior walls at 3rd level, some bearing interior and exterior walls on lower floors
LIGHT METAL FRAMING PRICE	$63,000 (Fall 1979)

PROJECT NAME:	Townhouse Garden Apartments- Commens II
PROJECT ADDRESS:	89 North Broadway, Town of White Plains, N.Y.
OWNER'S NAME & ADDRESS:	Howard Loewentheil & Son, Inc. 2251 Palmer Ave., New Rochelle, N.Y. 10801
DEVELOPER/GENERAL CONTRACTOR NAME & ADDRESS:	Same as above
ARCHITECTS NAME & ADDRESS:	Gismondi & Arnold, Architect, P.C. 235 Mamaroneck Ave., White Plains, N.Y. 10605
TYPE OF UNITS:	Condominiums
NUMBER OF UNITS:	44
NUMBER OF BUILDINGS:	2
TOTAL LIVING AREA:	69,900
SITE AREA:	66,734 sq. ft.
NUMBER OF STORIES:	3
LIGHT METAL FRAMING ITEMS INCLUDED:	Complete L.M.F. structural system at 3rd level and roof, floor joists on 1st and 2nd levels, and Mansards
LIGHT METAL FRAMING PRICE:	$275,000 (winter 80-81)
COST ESTIMATE BREAKDOWN:	labour - $122,000 material - 153,000
MAN HOUR SUMMARY:	erection - 6,867 m.h.

PROJECT NAME:	Townhouse Garden Apartments, Commons I
PROJECT ADDRESS:	North Broadway, City of White Plains, N.Y.
OWNER'S NAME & ADDRESS:	Howard Loewentheil & Son, Inc. 2251 Palmer Ave., New Rochelle, N.Y. 10801
DEVELOPER/GENERAL CONTRACTOR NAME & ADDRESS:	Same as above
ARCHITECTS NAME & ADDRESS:	Gismondi & Arnold, Architects, P.C. 235 Mamaroneck Ave. White Plains, N.Y. 10605
TYPE OF UNITS:	Condominiums
NUMBER OF UNITS:	33
NUMBER OF BUILDINGS:	2
TOTAL LIVING AREA:	52,404 sq. ft.
SITE AREA:	49,963 sq. ft.
NUMBER OF STORIES:	3
LIGHT METAL FRAMING ITEMS INCLUDED:	Complete L.M.F. structural system at 3rd level and roof, floor joists on 1st and 2nd levels.
LIGHT METAL FRAMING PRICE	$181,240 (summer 1979)

Townhouse Garden Apartments, Commons I
Townhouse Garden Apartments, Commons II
Scarsdale Meadows

These projects all fall into a catagory of developments investigated, whereby only portions of the completed buildings were done in light weight metal framing. For the most part these projects were done a number of years ago, and occurred before full acceptance of the light weight metal framing by the consulting community.

The light weight metal framing is combined in these instances with masonry construction, in order to reduce foundation costs where portions of the project occur on areas of fill.

In addition, light weight metal framing was used to reduce the cost of conventional wood framing and to achieve long span capabilities.

The total number of units per development varies from 33 - 60 units, and again represents a threshhold of economy where steel frame assemblies in low rise buildings may not compete with traditional forms of masonry construction. In the final analysis, the use of light weight metal framing in these buildings seems to have rested upon the individual preferance of the developers, consultants and others involved in the projects.

In many instances, details for balconies and other projects were simplified through the use of light weight metal framing, but in their simplification they would not be acceptable to Canadian standard. For the most part very low insulation standards were used in these buildings and acceptance of through wall connections and extensions for balconies were common occurrences.

It is difficult in many instances to adopt the construction standards used in these buildings to Canadian standards. Each project, however, was aesthetically pleasing and seems to have achieved in an economic sense the goals of the designers in choosing light weight metal framing.

SUMMARY

- LMF can be used in combination with masonry systems but may be at the individual preference of the designer rather than as a result of direct considerations.
- detailing for use of the system in Canada must reflect our climatic conditions.
- LMF would seem, in the author's opinion, to be subject to economies achieved in larger projects with repeated unit configurations.

11. TECHNICAL SECTION

Light Metal Framing

A. FRAMING COMPONENTS
1. Structural Members
2. Accessories
3. Fasteners/Framing Connections

B. CONSTRUCTION DETAILS
1. General Guidelines
2. Floor Systems
3. Wall Systems
4. Roof Systems
5. Bridging & Bracing Details

C. FABRICATION
1. Shop Drawings
2. Handlings & Transportation
3. Shop Layout
4. Construction Equipment

D. ERECTION
1. General Guidelines
2. Constructional Equipment
3. Procedure

E. TECHNICAL SUPPORT
1. General Guidelines
2. Fire Resistance Ratings
3. Sound Ratings
4. Thermal Performance
5. Industry Standards & Practices
6. Outline Specifications

F. MANUFACTURERS & SUPPLIERS
1. Addresses
2. Product Literature

G. BIBLIOGRAPHY

A. FRAMING COMPONENTS

1. Structural Members
2. Accessories
3. Fasteners/Framing Connections

Framing Components

This section has been developed to familiarize you with the basic components and fasterners that are available. Each major framing component has been assigned a general name which may vary from manufacturer to manufacturer. Included is a description of each component, the applications within the framing system for which it is best suited, and a range of sizes in which it is usually produced.

Although the basic configuration, size and use of the components are similar from one manufacturer to another, the terminology and specifications may vary slightly. Although these minor variations may at first confuse builders who are unfamiliar with steel framing systems, it will be seen that the specifications and quantities are no more difficult to understand than the section properties, grades and species of wood products.

Those factors which vary among manufacturers include such things as web size, web hold size and pattern, yield strength of the steel, the thickness (gage number) and flange size. Because of these differences the appropriate manufacturer's technical department should be consulted prior to design, selection of a component for a specific application, or proceeding with construction.

Although components made by different manufacturers can be used together on the same structure, it is generally recommended that a builder or a designer select one manufacturer and stay with that company's framing system throughout a given project.

Contents of this section:

Structural members -
1. Standard CEE
2. " "
3. Punched channel
4. Unpunched "
5. 1- channel

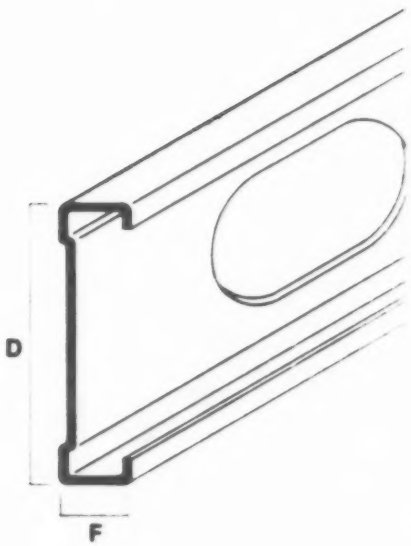
Framing accessories -
1. Cold formed angle
2. Cold rolled channel
3. Hat channel
4. V-bar
5. Reinforcement plate
6. strapping
7. Cold rolled zee

2.

Fasteners -
1. Bugle head screw
2. Oval head screw
3. Trim " "
4. low profile pan head screw
5. pan head screw
6. Hex washer head screw
7. pancake " "
8. screw-shank nail
9. fusion welding

Standard Cee

	Applications	
In Floor Systems	A Bridging	
In Wall Systems	A Blocking B Furring C Drywall Stud	D Lath & Plaster Stud E Curtainwall Stud F Non-Load Bearing Stud
In Roof Systems	A Stiffback Bracing B Soffit Framing C Lookout	D Truss Blocking E Furring F Ceiling Joist



Available Sizes

1¼" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage	●	●	●	●	●	●	●	●	●		●			
20 Gage	●	●	●	●	●	●	●		●		●			
18 Gage														
16 Gage														
14 Gage														
12 Gage														

1⅝" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage	●	●	●	●		●	●		●					
20 Gage	●	●	●	●		●	●		●					
18 Gage														
16 Gage														
14 Gage														
12 Gage														

1⅜" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage	●	●	●		●	●	●		●		●			
20 Gage	●		●		●	●	●		●					
18 Gage					●	●	●		●					
16 Gage														
14 Gage														
12 Gage														

1⅝" Flange Width (F)

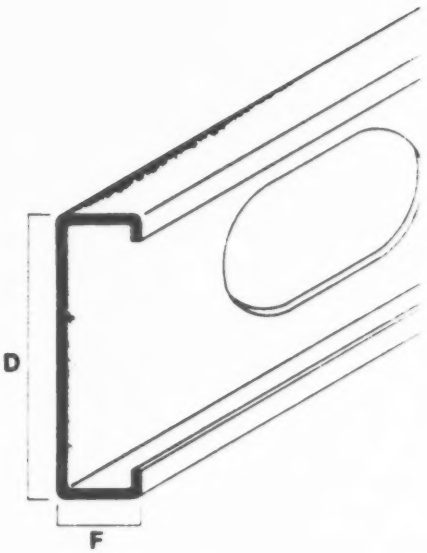
Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage	●		●			●	●		●					
20 Gage	●		●			●	●		●					
18 Gage														
16 Gage														
14 Gage														
12 Gage														

Manufacturers

A D S Steel Products Ltd
Allied Structural Industries
Bostwick Steel Framing Company
Ceco Corporation
Dale Industries, Inc
Evon Industries, Inc
Gold Bond Building Products
Harrison Manufacturing Co
INRYCO, Inc., Milcor Division
Marino Industries Corporation
Roper Eastern
Steel Systems Int'l, Inc
Western Metal Lath Company

Structural Cee

	Applications	
In Floor Systems	A Floor Joist B Rim Joist C Web Stiffener	D Solid Blocking E Built-up Beam
In Wall Systems	A Load-Bearing Stud B Lintel/Header	C Blocking
In Roof Systems	A Roof Rafter B Ceiling Joist C Collar Tie D King Post E Truss Member	F Ridge Board G Stiffback Bracing H Web Stiffener I Blocking



Available Sizes

1⅜" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
22 Gage			●	●	●	●	●		●					
20 Gage			●	●	●	●	●		●					
18 Gage			●	●	●	●	●		●					
16 Gage			●	●	●	●	●		●					
14 Gage			●		●	●	●		●					
12 Gage														

1⅝" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
22 Gage			●		●	●	●		●		●			
20 Gage			●		●	●	●	●	●		●			
18 Gage			●		●	●	●	●	●	●	●	●	●	●
16 Gage			●		●	●	●	●	●	●	●	●	●	●
14 Gage			●		●	●	●	●	●	●	●	●	●	●
12 Gage						●	●		●		●		●	●

2" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
22 Gage						●	●		●	●	●			
20 Gage						●	●		●	●	●	●	●	
18 Gage						●	●		●	●	●	●	●	●
16 Gage						●			●		●	●	●	●
14 Gage														
12 Gage														

2½" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
22 Gage						●	●		●					
20 Gage						●	●		●	●	●	●		
18 Gage						●	●		●	●	●	●	●	●
16 Gage						●	●		●		●	●	●	●
14 Gage														
12 Gage														

Manufacturers

Alabama Metal Industries Corp
Allied Structural Industries
Bailey Metal Products Limited
Bostwick Steel Framing Company
Ceco Corporation
Dale Industries, Inc
Evon Industries, Inc
INRYCO, Inc., Milcor Division
Marino Industries Corporation
Monex Corporation
Steel Systems Int'l Inc
United States Gypsum Company
United States Steel (Licensees)
Vulcan Metal Products, Inc
Western Metal Lath Company
Wheeling Corrugating Company

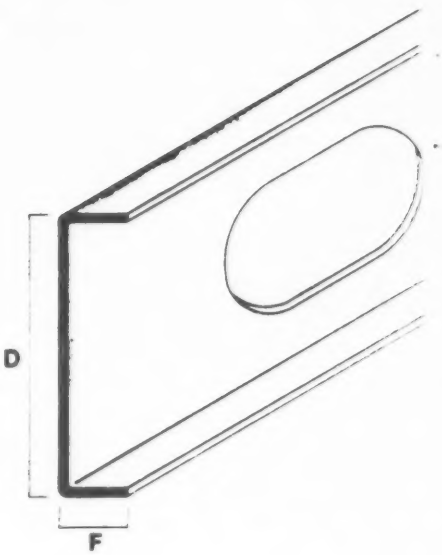
Structural Cee (cont'd.)

Available Sizes

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
1¼" Flange Width (F)														
22 Gage			●	●		●	●		●		●			
20 Gage			●	●		●	●		●		●			
18 Gage			●	●		●	●		●		●			
16 Gage			●	●		●	●		●		●			
14 Gage			●	●		●	●		●		●			
12 Gage											●			
1½" Flange Width (F)														
22 Gage				●	●									
20 Gage				●	●									
18 Gage				●	●									
16 Gage				●	●									
14 Gage														
12 Gage														
1¾" Flange Width (F)														
22 Gage								●		●				
20 Gage								●		●		●		
18 Gage								●		●		●		
16 Gage												●		
14 Gage														
12 Gage														

Structural Cee
Punched Channel

	Applications	
In Floor Systems	A Web Stiffener	
In Wall Systems	A Load-Bearing Stud B Curtainwall Stud	C Drywall Stud D Lath & Plaster Stud
In Roof Systems	A Sub-Fascia	B Blocking



Available Sizes

½" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage	●	●	●		●	●	●		●					
20 Gage	●	●	●		●	●	●		●					
18 Gage														
16 Gage														
14 Gage														
12 Gage														

1" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage			●		●	●			●					
20 Gage			●		●	●	●		●					
18 Gage			●		●	●	●		●					
16 Gage			●		●	●	●		●					
14 Gage			●			●	●		●					
12 Gage						●	●		●					

1¼" Flange Width (F)

Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage			●		●	●	●		●					
20 Gage			●		●	●	●		●					
18 Gage			●		●	●	●		●					
16 Gage			●		●	●	●		●					
14 Gage														
12 Gage														

1⅜" Flange Width (F)

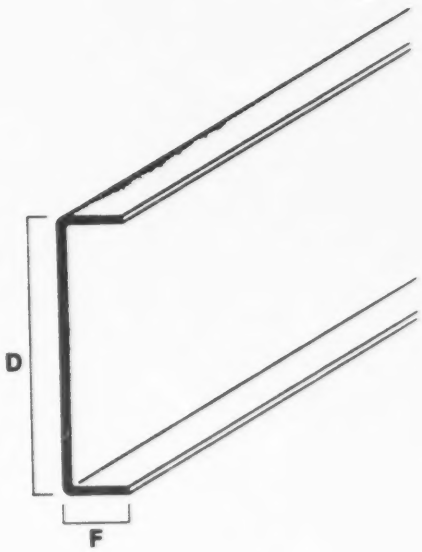
Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage			●			●	●		●		●			
20 Gage			●			●	●		●		●			
18 Gage			●			●	●		●		●			
16 Gage			●			●	●		●		●			
14 Gage			●			●	●		●		●			
12 Gage						●	●		●					

Manufacturers

Alabama Metal Industries Corp
Allied Structural Industries
Bostwick Steel Framing Company
Ceco Corporation
Evon Industries, Inc.
INRYCO, Inc., Milcor Division
Monex Corporation
Steel Systems Int'l. Inc.
Western Metal Lath Company
Wheeling Corrugating Company

Unpunched Channel

	Applications	
In Floor Systems	A. Rim Track	B. Bridging
In Wall Systems	A. Plate Track B. Lateral Bracing C. Blocking	D. Window Sill E. Lintel Component
In Roof Systems	A. Fascia B. Sub-Fascia	C. Blocking



Available Sizes

29/32" Flange Width (F)

Web Depth (D)	1 3/16	2 5/16	2 11/16	3 7/16	3 13/16	4 7/16	5 13/16	6 7/16	7 7/16	8 7/16	8 3/8	9 7/16	10 7/16	12 7/16
25 Gage			●		●	●		●						
20 Gage			●		●	●		●		●				
18 Gage														
16 Gage														
14 Gage														
12 Gage														

1" Flange Width (F)

Web Depth (D)	1 3/16	2 5/16	2 11/16	3 7/16	3 13/16	4 7/16	5 13/16	6 7/16	7 7/16	8 7/16	8 3/8	9 7/16	10 7/16	12 7/16
25 Gage	●		●					●		●				
20 Gage	●		●					●		●				
18 Gage	●		●					●		●				
16 Gage	●		●					●		●				
14 Gage	●		●					●		●				
12 Gage								●						

1 5/16" Flange Width (F)

Web Depth (D)	1 3/16	2 5/16	2 11/16	3 7/16	3 13/16	4 7/16	5 13/16	6 7/16	7 7/16	8 7/16	8 3/8	9 7/16	10 7/16	12 7/16
25 Gage			●		●	●	●	●						
20 Gage		●	●	●	●	●	●	●	●	●	●			
18 Gage		●	●	●	●	●	●	●	●	●	●	●	●	●
16 Gage					●	●		●	●	●	●	●	●	●
14 Gage														
12 Gage														

1 3/8" Flange Width (F)

Web Depth (D)	1 3/16	2 5/16	2 11/16	3 7/16	3 13/16	4 7/16	5 13/16	6 7/16	7 7/16	8 7/16	8 3/8	9 7/16	10 7/16	12 7/16
25 Gage			●		●	●		●						
20 Gage			●		●	●		●						
18 Gage			●		●	●		●						
16 Gage					●	●		●						
14 Gage					●	●		●						
12 Gage								●						

Manufacturers

A.D.S. Steel Products Ltd.
Alabama Metal Industries Corp.
Allied Structural Industries
Bailey Metal Products Limited
Bostwick Steel Framing Company
Ceco Corporation
Dale Industries, Inc.
Evon Industries, Inc.
Harrison Manufacturing Co.
INRYCO, Inc., Milcor Division
Marino Industries Corporation
Monex Corporation
Steel Systems Int'l. Inc.
United States Gypsum Company
United States Steel (licensees)
Western Metal Lath Company
Wheeling Corrugating Company

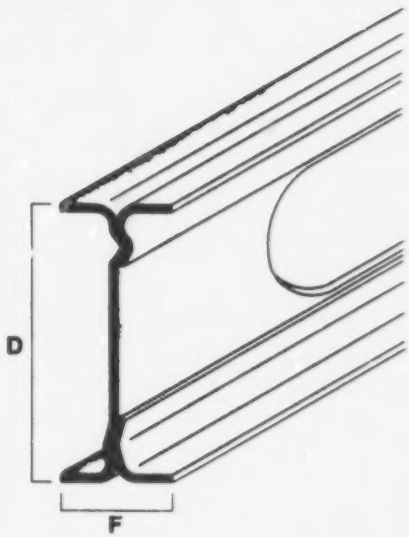
Unpunched Channel (cont'd.)

Available Sizes

Web Depth (D)	1 3/16	2 5/16	2 11/16	3 7/16	3 13/16	4 3/16	5 13/16	6 3/16	7 1/16	8 3/16	8 3/8	9 7/16	10 3/16	12 3/16
¾" Flange Width (F)														
25 Gage		●	●	●	●	●	●	●		●				
20 Gage			●		●	●		●		●			●	●
18 Gage														
16 Gage														
14 Gage														
12 Gage														
1⅛" Flange Width (F)														
25 Gage	●		●		●	●		●						
20 Gage			●		●	●		●						
18 Gage														
16 Gage														
14 Gage														
12 Gage														
1¼" Flange Width (F)														
25 Gage	●		●	●	●	●		●		●				
20 Gage	●		●	●	●	●		●						
18 Gage			●		●	●		●		●				
16 Gage			●		●	●		●		●				
14 Gage														
12 Gage														
1⅝" Flange Width (F)														
25 Gage					●	●		●						
20 Gage					●	●		●		●				
18 Gage					●	●		●		●				
16 Gage					●	●		●		●			●	
14 Gage					●	●		●		●			●	
12 Gage					●	●		●		●			●	

I-Channel

	Applications	
In Floor Systems	A. Floor Joist	
In Wall Systems	A. Load-Bearing Stud	B. Lintel/Header
In Roof Systems	A. Roof Rafter B. Ceiling Joist	C. Truss Component



Available Sizes

	1 13/16" Flange Width (F)													
Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage						●								
20 Gage														
18 Gage														
16 Gage														
14 Gage														
12 Gage														

	1 15/16" Flange Width (F)													
Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage						●	●							
20 Gage														
18 Gage														
16 Gage														
14 Gage														
12 Gage														

	2¼" Flange Width (F)													
Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage													●	●
20 Gage														
18 Gage														
16 Gage														
14 Gage														
12 Gage														

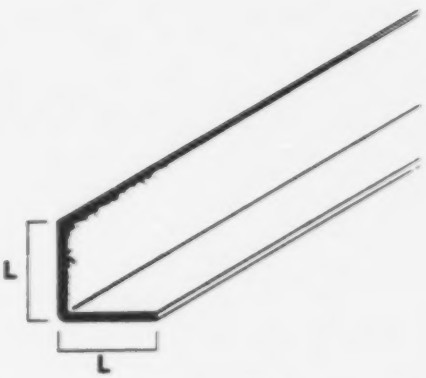
	2 13/16" Flange Width (F)													
Web Depth (D)	1⅝	2	2½	3¼	3½	3⅝	4	5½	6	7¼	8	9¼	10	12
25 Gage													●	●
20 Gage														
18 Gage														
16 Gage														
14 Gage														
12 Gage														

Manufacturers

Gold Bond Building Products
Wheeling Corrugating Company

Cold Rolled Angle

	Applications	
In Floor Systems	A. Joist End Reinforcement B. Ledger	C. Connection Bracket D. Connection Clip
In Wall Systems	A. Lateral Bracing B. Connection Clip	C. Blocking
In Roof Systems	A. Utility Bracket B. Stiffback Bracing C. Blocking	D. Connection Anchor E. Connection Clip



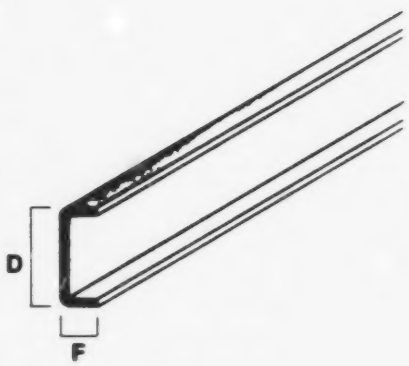
	Available Sizes											
	Leg Length (L)											
Web Depth (D)	½	⅝	⅞	1	1¼	1⅜	1½	1⅝	2	2¼	2½	3
25 Gage	●	●	●	●	●	●	●	●	●		●	●
22 Gage				●	●	●	●					●
20 Gage			●	●	●	●	●	●	●		●	●
18 Gage			●	●	●	●	●		●		●	●
16 Gage			●	●	●	●	●		●		●	●
14 Gage				●	●		●		●			●

Manufacturers

Allied Structural Industries
Dale Industries, Inc.
Gold Bond Building Products
INRYCO, Inc., Milcor Division
Marino Industries Corporation
Steel Systems Int'l. Inc.
United States Gypsum Company
United States Steel (licensees)
Wheeling Corrugating Company

Cold Rolled Channel

	Applications	
In Floor System	A. Joist End Connector	
In Wall Systems	A. Lateral Bracing B. Wall Stiffener C. Furring	D. Blocking E. Ladder-Back
In Roof Systems	A. Blocking	B. Bracing



Available Sizes

⅜" Leg Length (L)

Web Depth (D)	½	⅝	¾	⅞	1	1½	2	2¼	3	3¼	3½	4	6	8
25 Gage						●								
22 Gage			●			●	●							
20 Gage														
18 Gage														
16 Gage														
14 Gage														

½" Leg Length (L)

Web Depth (D)	½	⅝	¾	⅞	1	1½	2	2¼	3	3¼	3½	4	6	8
25 Gage			●			●	●							
22 Gage														
20 Gage														
18 Gage														
16 Gage														
14 Gage														

¾" Leg Length (L)

Web Depth (D)	½	⅝	¾	⅞	1	1½	2	2¼	3	3¼	3½	4	6	8
25 Gage	●		●			●	●		●	●		●	●	●
22 Gage														
20 Gage														
18 Gage								●						
16 Gage					●			●						
14 Gage														

⅞" Leg Length (L)

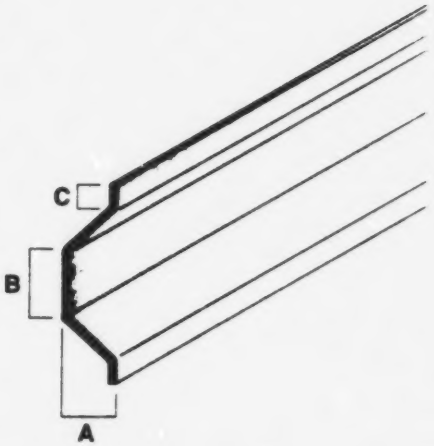
Web Depth (D)	½	⅝	¾	⅞	1	1½	2	2¼	3	3¼	3½	4	6	8
25 Gage			●			●	●							
22 Gage														
20 Gage														
18 Gage														
16 Gage														
14 Gage														

Manufacturers

A.D.S. Steel Products Ltd.
Allied Structural Industries
Dale Industries, Inc.
Gold Bond Building Products
INRYCO, Inc., Milcor Division
Marino Industries Corporation
Steel Systems Int'l. Inc.
United States Steel (licensees)
Western Metal Lath Company
Wheeling Corrugating Company

Hat Channel

	Applications	
In Floor Systems	A. Furring	
In Wall Systems	A. Furring	B. Jamb Anchor
In Roof Systems	A. Furring	



Available Sizes

⅞" Channel Depth (A)						
Face Width (B)	1¼		1⅜		3	
Flange Width (C)	⅜	½	⅜	½	⅜	½
25 Gage	●	●	●			
22 Gage	●	●				
20 Gage	●	●	●			
18 Gage	●	●	●			
16 Gage	●	●				

1" Channel Depth (A)						
Face Width (B)	1¼		1⅜		3	
Flange Width (C)	⅜	½	⅜	½	⅜	½
25 Gage					●	
22 Gage					●	
20 Gage					●	
18 Gage						
16 Gage						

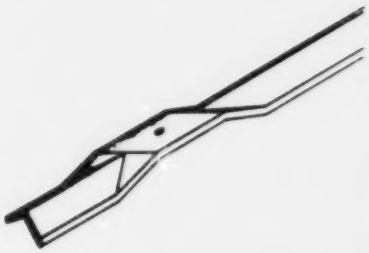
1½" Channel Depth (A)						
Face Width (B)	1¼		1⅜		3	
Flange Width (C)	⅜	½	⅜	½	⅜	½
25 Gage	●					
22 Gage	●		●			
20 Gage	●					
18 Gage	●					
16 Gage	●					

Manufacturers

Allied Structural Industries
Bostwick Steel Framing Company
Dale Industries, Inc.
Gold Bond Building Products
Harrison Manufacturing Co.
INRYCO, Inc., Milcor Division
Marino Industries Corporation
Steel Systems Int'l. Inc.
Western Metal Lath Company

V-Bar

	Applications
In Floor Systems	A. Bridging
In Wall Systems	A. Lateral Bracing
In Roof Systems	A. Bridging



Available Sizes

16, 18 and 20 Gage

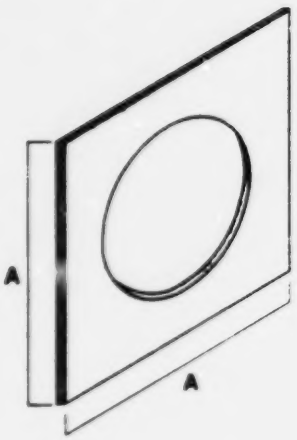
For 16" on center
and 24" on center

Manufacturers

United States Gypsum Company
Wheeling Corrugating Company

Reinforcement Plate

	Applications	
In Floor Systems	A. Web Hole Reinforcement	
In Wall Systems	A. Web Hole Reinforcement	B. Header Gusset
In Roof Systems	A. Web Hole Reinforcement	B. Truss Gusset



Available Sizes

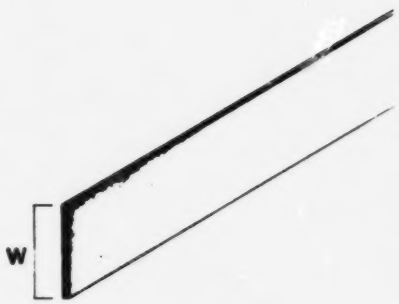
Gages	Edges (A)	Hole Diameters
12	5 1/4 × 5 1/4	3 1/2
14	7 × 7	4 1/4
	7 1/8 × 7 1/8	5 1/8
	9 × 9	5 1/4
	9 1/8 × 9 1/8	6 7/8
		7 1/4

Manufacturers

Marino Industries Corporation
United States Gypsum Company
United States Steel (licensees)

Strapping

	Applications	
In Floor Systems	A. Bridging	
In Wall Systems	A. Diagonal Windbrace B. Lateral Bracing	C. Brick Tie
In Roof Systems	A. Bridging	



Available Sizes

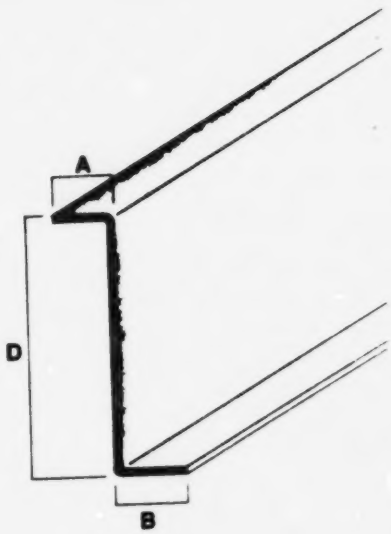
	Width (W)												
Web Depth (D)	¾	1	1½	1⅝	2	2½	2¾	3	3¼	3½	3⅝	4	4½	5
25 Gage		●												
20 Gage		●			●							●		
18 Gage		●												
16 Gage		●			●									
14 Gage		●			●			●				●		
12 Gage		●						●				●		●

Manufacturers

Allied Structural Industries
INRYCO, Inc., Milcor Division
Marino Industries Corporation
Monex Corportion
Steel Systems Int'l Inc
United States Gypsum Company
United States Steel (licensees)
Western Metal Lath Company
Wheeling Corrugating Company

Cold Rolled Zee

	Applications	
In Floor Systems	A. Girt	
In Wall Systems	A. Drywall Attachment B. Jamb Anchor	C. Furring
In Roof Systems	A. Purlin	B. Furring



Available Sizes

1¼"/¾" Flange Width (A/B)

Web Depth (D)	½	⅝	¾	1	1½	1¾	2	2½	3	3½	4	6	8	10
25 Gage			●	●	●			●	●	●	●			
22 Gage														
20 Gage				●	●			●						
18 Gage				●	●			●						
16 Gage														
14 Gage														

1¼"/1" Flange Width (A/B)

Web Depth (D)	½	⅝	¾	1	1½	1¾	2	2½	3	3½	4	6	8	10
25 Gage	●	●		●	●		●							
22 Gage	●	●		●	●		●							
20 Gage	●	●		●	●		●							
18 Gage	●	●		●	●		●							
16 Gage	●	●		●	●		●							
14 Gage	●	●		●	●		●							

2½"/2½" Flange Width (A/B)

Web Depth (D)	½	⅝	¾	1	1½	1¾	2	2½	3	3½	4	6	8	10
25 Gage												●		
22 Gage												●		
20 Gage												●		
18 Gage												●		
16 Gage												●	●	
14 Gage												●	●	●

3"/3" Flange Width (A/B)

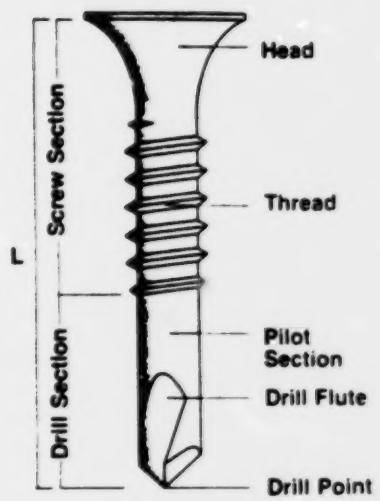
Web Depth (D)	½	⅝	¾	1	1½	1¾	2	2½	3	3½	4	6	8	10
25 Gage													●	
22 Gage													●	
20 Gage													●	
18 Gage													●	
16 Gage													●	
14 Gage													●	●

Manufacturers

Allied Structural Industries
American Building Products
Dale Industries, Inc.
Gold Bond Building Products
Marino Industries Corporation
Steel Systems Int'l. Inc.
Western Metal Lath Company

Bugle Head Screw

	Applications	
In Floor Systems	A Joist to Wood Sill B Sheathing to Joist	C Subflooring to Joist
In Wall Systems	A Drywall to Stud B Sheathing to Stud	C Furring to Lath B Rigid Insulation to Stud
In Roof Systems	A Drywall to Rafter B Sheathing to Rafter	C Drywall to Ceiling Joist D Rigid Insulation to Rafter



Available Sizes

Screw Length (L) with Pilot Section														
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S						●	●	●	●	●	●			●
S-7														
S-12							●	●	●	●				
Teks 2														
Teks 3														
Teks 4														

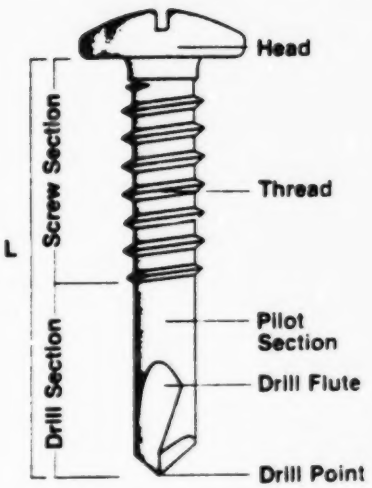
Screw Length (L) without Pilot Section														
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S	●	●	●			●			●		●			
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

Manufacturers

Buildex Division of Illinois Tool Works, Inc
Building Fasteners Inc
Camcar Div of Textron, Inc
Construction Fastener, Inc
ELCO Industries, Inc
Fabco Fastening Systems
Flintkote Building Material Division
Guardian Fasteners and Closure Systems
Milcor Div of Inryco, Inc
National Lock Fasteners
New Pneutec, Inc
Parker Kalon, Emhart Unit
Sierra Fasteners, Inc
United States Gypsum Company

Oval Head Screw

	Applications	
In Floor Systems	A Trim Moulding to Joist	
In Wall Systems	A Wood Cabinet to Stud	B Trim Moulding to Stud
In Roof Systems	A Trim Moulding to Rafter	



Available Sizes

Screw Length (L) with Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S							●	●		●		●		●
S-7														
S-12					●									
Teks 2														
Teks 3														
Teks 4														

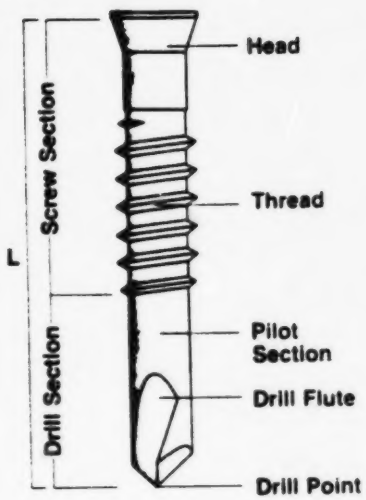
Screw Length (L) without Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S														
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

Manufacturers

Buildex Division of Illinois Tool Works, Inc
Building Fasteners Inc
Camcar Div. of Textron, Inc
Construction Fastener, Inc
ELCO Industries, Inc
Fabco Fastening Systems
Flintkote Building Material Division
Guardian Fasteners and Closure Systems
Milcor Div. of Inryco, Inc
National Lock Fasteners
New Pneutec, Inc.
Parker Kalon, Emhart Unit
Sierra Fasteners, Inc.
United States Gypsum Company

Trim Head Screw

	Applications
In Floor Systems	A. Trim Moulding to Joist
In Wall Systems	A. Wood Trim to Stud
In Roof Systems	A. Trim Attachment



Available Sizes

Screw Length (L) with Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S							●		●		●			
S-7														
S-12							●		●		●			
Teks 2														
Teks 3														
Teks 4														

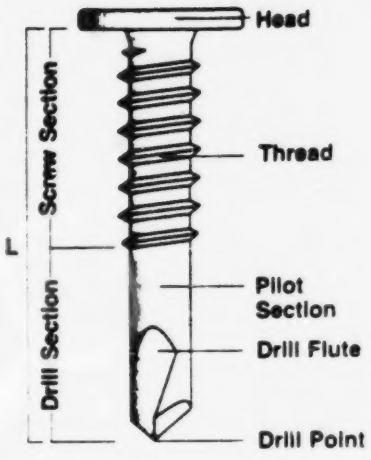
Screw Length (L) without Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S														
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

Manufacturers

Buildex Division of Illinois Tool Works, Inc
Building Fasteners Inc
Camcar Div of Textron, Inc
Construction Fastener, Inc
ELCO Industries, Inc
Fabco Fastening Systems
Flintkote Building Material Division
Guardian Fasteners and Closure Systems
Milcor Div of Inryco, Inc
National Lock Fasteners
New Pneutec, Inc
Parker Kalon, Emhart Unit
Sierra Fasteners, Inc
United States Gypsum Company

Low-Profile Pan Head Screw

	Applications	
In Floor Systems	A. Joist to Rim Track B. Joist to Web Stiffener C. Connection Clip to Joist D. Bridging to Joist	E. Solid Blocking to Joist F. Built-up Beam Assembly G. Joist Hanger to Joist H. Joist to Overlapping Joist
In Wall Systems	A. Stud to Plate Track B. Ladder-Back to Stud C. Stud to Stud D. Windbrace to Stud E. Lateral Bracing to Stud	F. Gusset to Stud & Header G. Window Sill to Stud H. Lintel Assembly I. Steel Jamb to Stud
In Roof Systems	A. Subfascia to Rafter B. Rafter to Rafter C. Bracing to Rafter D. Bridging to Rafter	E. Gusset to Rafter F. Rafter to Web Stiffener G. Ridge Board Assembly



Available Sizes

Screw Length (L) with Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S		●		●										
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

Screw Length (L) without Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S														
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

Manufacturers

Buildex Division of Illinois Tool Works, Inc.
Building Fasteners Inc.
Camcar Div. of Textron, Inc.
Construction Fastener, Inc.
ELCO Industries, Inc.
Fabco Fastening Systems
Flintkote Building Material Division
Guardian Fasteners and Closure Systems
Milcor Div. of Inryco, Inc.
National Lock Fasteners
New Pneutec, Inc.
Parker Kalon, Emhart Unit
Sierra Fasteners, Inc.
United States Gypsum Company

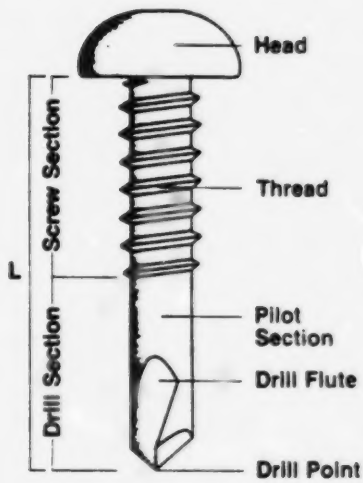
Pan Head Screw

	Applications	
In Floor Systems	A. End Stiffener to Rim B. Connection Clip to Joist C. Joist to Web Stiffener D. Bridging to Joist	E. Solid Blocking to Joist F. Built-up Beam Assembly G. Joist Hanger to Joist H. Joist to Overlapping Joist
In Wall Systems	A. Stud to Plate Track B. Ladder-Back to Stud C. Stud to Stud D. Windbrace to Stud	E. Lateral Bracing to Stud F. Gusset to Stud & Header G. Window Sill to Stud H. Lintel Assembly
In Roof Systems	A. Subfascia to Rafter B. Rafter to Rafter C. Collar Tie to Rafter D. Bridging to Rafter E. Rafter to Ceiling Joist	F. Gusset to Rafter G. King Post to Rafter H. Truss Web to Rafter I. Bracing to Rafter J. Rafter to Web Stiffener

Available Sizes

Screw Length (L) with Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S		●												
S-7			●											
S-12		●	●		●									
Teks 2														
Teks 3														
Teks 4														

Screw Length (L) without Pilot Section													
Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S														
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														



Manufacturers

Buildex Division of Illinois Tool Works, Inc.
Building Fasteners Inc.
Camcar Div. of Textron, Inc.
Construction Fastener, Inc.
ELCO Industries, Inc.
Fabco Fastening Systems
Flintkote Building Material Division
Guardian Fasteners and Closure Systems
Milcor Div. of Inryco, Inc.
National Lock Fasteners
New Pneutec, Inc.
Parker Kalon, Emhart Unit
Sierra Fasteners, Inc.
United States Gypsum Company

Hex Washer Head Screw

	Applications	
In Floor Systems	A. End Stiffener to Rim B. Connection Clip to Joist C. Joist to Web Stiffener D. Bridging to Joist	E. Solid Blocking to Joist F. Built-up Beam Assembly G. Joist Hanger to Joist H. Joist to Overlapping Joist
In Wall Systems	A. Stud to Plate Track B. Ladder-Back to Stud C. Stud to Stud D. Windbrace to Stud	E. Lateral Bracing to Stud F. Gusset to Stud & Header G. Window Sill to Stud H. Lintel Assembly
In Roof Systems	A. Subfascia to Rafter B. Rafter to Rafter C. Collar Tie to Rafter D. Bridging to Rafter E. Rafter to Ceiling Joist	F. Gusset to Rafter G. King Post to Rafter H. Truss Web to Rafter I. Bracing to Rafter J. Rafter to Web Stiffener

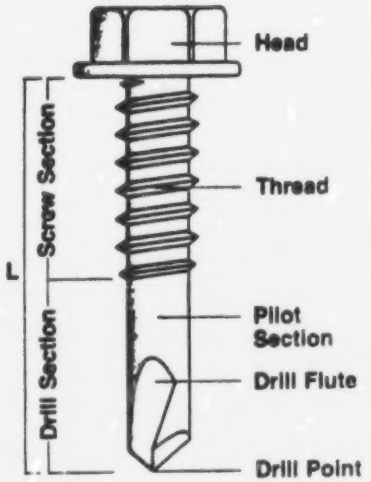
Available Sizes

Screw Length (L) with Pilot Section

Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S		●												
S-7														
S-12	●	●		●		●								
Teks 2			●	●		●	●	●			●		●	
Teks 3					●									
Teks 4														

Screw Length (L) without Pilot Section

Point Type	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 5/8	1 7/8	2 1/4	2 1/2	2 7/8	3	3 3/4
S														
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

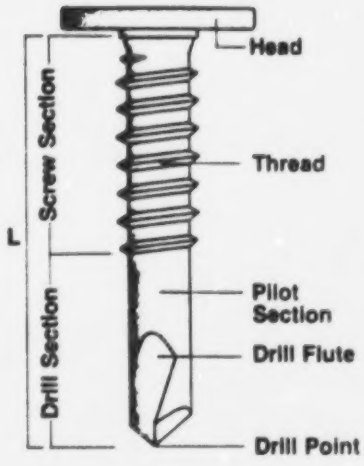


Manufacturers

Buildex Division of Illinois Tool Works, Inc.
Building Fasteners Inc.
Camcar Div. of Textron, Inc.
Construction Fastener, Inc.
ELCO Industries, Inc.
Fabco Fastening Systems
Flintkote Building Material Division
Guardian Fasteners and Closure Systems
Milcor Div. of Inryco, Inc.
National Lock Fasteners
New Pneutec, Inc.
Parker Kalon, Emhart Unit
Sierra Fasteners, Inc.
United States Gypsum Company

Pancake Head Screw

	Applications	
In Floor Systems	A. Metal Lath to Joist B. Joist to Wood Web Stiffener	C. Joist to Wood End Stiffener D. Joist to Wood Sill
In Wall Systems	A. Metal Lath to Stud	B. Stud to Wood Web Stiffener
In Roof Systems	A. Metal Lath to Rafter B. Rafter to Wood Web Stiffener	C. Ceiling Joist to Wood End Stiffener



Available Sizes

Screw Length (L) with Pilot Section													
Point Type	⅜	½	⅝	¾	⅞	1	1¼	1⅝	1⅞	2¼	2½	2⅞	3	3¾
S		●					●							
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

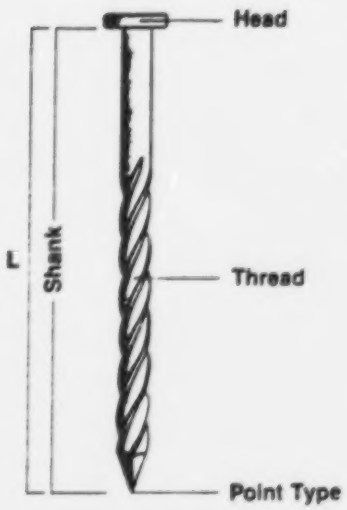
Screw Length (L) without Pilot Section													
Point Type	⅜	½	⅝	¾	⅞	1	1¼	1⅝	1⅞	2¼	2½	2⅞	3	3¾
S														
S-7														
S-12														
Teks 2														
Teks 3														
Teks 4														

Manufacturers

Buildex Division of Illinois Tool Works, Inc.
Building Fasteners Inc.
Camcar Div. of Textron, Inc.
Construction Fastener, Inc.
ELCO Industries, Inc.
Fabco Fastening Systems
Flintkote Building Material Division
Guardian Fasteners and Closure Systems
Milcor Div. of Inryco, Inc.
National Lock Fasteners
New Pneutec, Inc.
Parker Kalon, Emhart Unit
Sierra Fasteners, Inc.
United States Gypsum Company

Screw-Shank Nail

	Applications	
In Floor Systems	A. Sheathing to Joist	B. Subflooring to Joist
In Wall Systems	A. Sheathing to Stud B. Drywall to Stud	C. Ridge Insulation to Stud
In Roof Systems	A. Sheathing to Rafter B. Rigid Insulation to Rafter	C. Furring to Rafter D. Drywall to Ceiling Joist



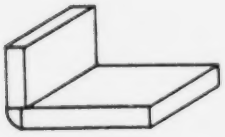
Common Sizes

	Length of Nail (L)								
Point Type	1⅛	1¼	1⅝	1¾	2	2⅛	2¼	2½	3
Standard					●		●	●	●
Ballistic	●	●	●	●	●	●	●		

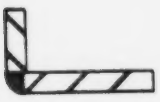
Manufacturers

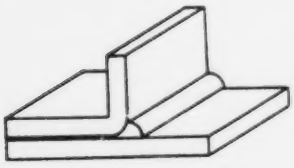
Construction Fastener, Inc.
Flintkote Building Material Division
New Pneutec, Inc.
Senco Fastening Systems
Sierra Fasteners, Inc.
Tree Island Product

Fusion Welding

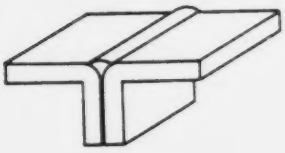


Angle Joint with Flare-Bevel Edge Weld

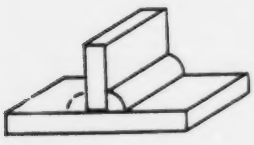




Flat Joint with Flare-Bevel Groove Weld

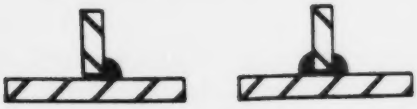


Flat Joint with Flare V-Groove Weld



Tee Joint with Single Fillet Weld

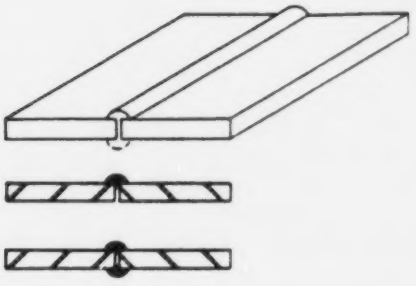
with Double Fillet Weld



Fusion Welding (cont'd.)

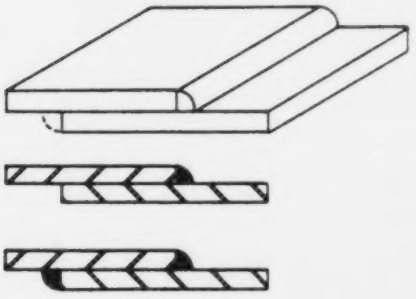
Butt Joint with Single Square Groove Weld

with Double Square Groove Weld

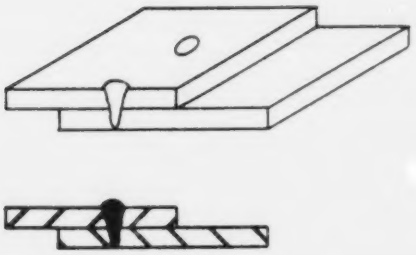


Lap Joint with Edge Fillet Weld

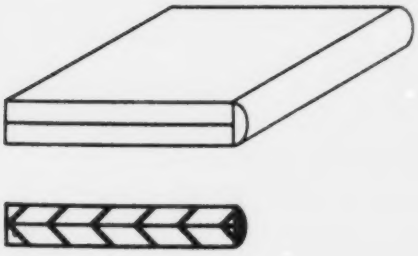
with Double Fillet Weld



Lap Joint with CO, Spot Weld



Leaf Joint with Back Weld



FRAMING CONNECTIONS

Strong, uncomplicated, and economical connections are very important for any structural member to perform to its design capacity.

The connection of cold-formed structural steel framing members is usually accomplished by welding, or by use of self-drilling, self-tapping screws. Both methods combine strength and economy attributes.

WELDING

Fusion welding is the most popular method for the contractor to connect steel framing members. Resistance welds may occasionally have merit, although paint or zinc coating will frequently interfere with the structural connection reliability.

The fusion welds generally used for connecting cold-formed steel framing components to each other, or to hot-rolled structural components, are fillet welds, butt welds, plug welds and arc-spot welds (puddle welds).

Fillet welds and plug welds are suitable whenever the metal being joined is lapped. With fillet welds, if the weld is parallel to the direction of the applied force, it is longitudinal; and if it is perpendicular, then it is transverse. Transverse welds are stronger, per inch of weld, than longitudinal welds because they are more uniformly stressed along the entire length. Plug welds are circular fillet welds where one of the base metals is prepunched to accommodate the weld. The strength of plug welds, per inch of weld (the length of the plug weld is considered to be the perimeter of the hole), is close to that of transverse welds.

Two types of fusion welding are common:

1. **Shielded Metal**—Arch Welding (SMAW) is an arc-welding process wherein the arc supplies the heat needed to melt the base metal surfaces being joined and the filler metal, which then fuse together. The filler metal is provided by a consumable coated electrode which establishes the arc and gradually melts away, filling the joint. The shielding is accomplished by the melting of the coating on the electrode. Good welds may be obtained with 3/32" or 1/8" diameter AWS type E-6012, E-6013 or E-7014 rod. The equipment heat setting will vary depending on material thickness. A 200 amp "hot box" electric welder or 200 amp gasoline generator-welder is adequate for SMAW (stick welding) cold-formed steel framing.
2. **Gas Metal**—Arc Welding (GMAW) is an arc-welding process in which the arc is shielded by a chemically inert gas, such as Argon or CO_2. This process is often called inert-gas welding for short; or, more specifically, when a consumable metal electrode is used, metal inert-gas welding (MIG). In MIG welding, the electrode is mechanically fed into the arc. This type of welding is most economical for shop conditions. Good welds may be obtained with AWS E-705-3, -5 or -6 wire electrode in .030" to .35" diameter using CO_2, Argon-oxygen, or Argon CO_2 gash shielding.

   For GMAW (MIG welding), a wirefeed welder with a capacity of 60-110 amps. and approximately 23 volts variable output is suggested. This type equipment requires 220 volt electric service.

DESIGN OF WELDING CONNECTIONS

The purpose of any connection is to permit the structural member being joined to perform to its ultimate capacity. Therefore, all connections should be designed to transmit the maximum stress in the connected member with proper regard for eccentricity. If members are subject to reversals in stress, except if caused by wind or earthquake loads, the connection should be designed for the sum of the stress. Connections subject only to stresses from wind or earthquake loads may be portioned for stress 33⅓ percent greater than those specified for dead and live load stresses, in accordance with A.I.S.I. Specification for the Design of Cold-Formed Steel Structural Members, Section 3.1.2.1.

Fillet welds and plug welds should be positioned so that they are subject to shearing stress only. The allowable shear may be computed by multiplying the allowable weld shear stress by the throat area of the weld. However, the throat thickness dimension shall not exceed the thickness of the thinnest member being connected. Permissible shear stress values for fusion welds are given in the A.I.S.I. Specification, Section 4.2.1.

Allowable shearing force per inch of weld based on 13,600 psi design stress, and on full thickness penetration area as follows:

Steel Gage	Design Thickness	Allowable Shear (Lbs./Lin. Inch)
12	.1046	1005
14	.0747	718
16	.0598	575
18	.0478	460
20	.0359	345

Butt welds are considered to be as strong as the lower grade or base metals being joined for both tension and compression stress. This is provided the weld penetrates 100 percent of the section and the yield strength of the filler metal meets or exceeds the yield strength of the base metal. Stresses due to eccentric loading should be combined with the primary stresses.

SCREW ATTACHMENT

Self-drilling, self-tapping screws are also used for connection of steel framing members. This type of screw drills its own hole through the two pieces to be joined, then taps a thread in both pieces in fastening them together.

In addition to connecting two framing members, this type screw is also used for connection of other metals, wood, decking, numerous wall facing materials, electrical components, clips and accessories.

A hand-held screw gun that operates at normally 2,500 RPM on 115-volt power is commonly used to drive these screws. The screws are available in a variety of head styles to fit particular requirements.

DESIGN OF SCREW CONNECTIONS

As with welded connections, screw attachments should be designed to transmit the maximum stress in the connected member with proper regard for eccentricity.

Suggested design shear and pullout loads for various size screws are listed in the following table.

SUGGESTED DESIGN LOAD IN POUNDS FOR SCREW CONNECTIONS

Steel Thickness Gage	No. 12-14 D = .177"		No. 10-16 D = .153"		No. 8-18 D = .125"		No. 6, S-12 D = .106"	
	Shear or Bearing	Pullout Pullout	Shear or Bearing	Pullout	Shear or Bearing	Pullout	Shear or Bearing	Pullout
12	861	610	N.A.	656	N.A.	536	N.A.	548
14	788	444	636	394	N.A.	388	N.A.	313
16	733	320	621	296	498	277	381	241
18	505	230	474	206	401	196	351	172
20	344	144	334	146	310	118	263	112

N.A.: Not applicable. Two thicknesses of this gage cannot be connected by this size screw.

NOTES:

1. Shear and pullout strength based on average test result divided by a safety factor of 2.5. Test data is available from screw manufacturers.
2. Bearing strength based upon: Bearing Area x 2.1 x F_y. F_y = 33,000 psi minimum.
3. Minimum screw spacing and edge distance shall not be less than 1½D nor less than $P/.6F_y t$.
4. When connecting materials with different gages, use loads for the lighter gage.
5. Screws for driving into thicknesses greater than 12 gage are available, although not shown in the above table.
6. D = Screw shank diameter, and P = Shear load in the previous notes.

ANCHOR FASTENING

Power actuated fasteners and expansion masonry anchors are commonly used for attaching cold-formed steel framing to concrete slabs or footings. Power actuated fasteners may also be used for anchoring to hot-rolled structural steel.

POWER ACTUATED FASTENERS

The fasteners used in power actuated tools are manufactured from special steel, heat-treated to produce a very hard yet ductile fastener. The two basic types available are drive pins and threaded studs, although drive pins are used almost exclusively in cold formed steel frame construction.

The fasteners are normally driven by cased power loads, available in various sizes ranging from .22 through .38 caliber, and in various power levels for each size. The selection of proper power load is based upon the base material in which the fastener is being driven. Air guns are also available for driving some fasteners.

When a fastener is driven into concrete base material, the holding power results primarily from a compression bond of the concrete to the fastener shank. The fastener, on penetration, displaces the concrete which tries to return to its original form and exerts a squeezing effect.

Compression of concrete around the fastener shank takes place with the amount of compression increasing in relation to the depth of penetration and the compressive strength of the concrete.

Suggested design loads for power driven fasteners are shown in the following table.

SUGGESTED DESIGN LOAD FOR POWER DRIVEN FASTENERS
Allowable working values in stone aggregate concrete (lbs.)

Type of Shot	Shank Diameter	Minimum Penetration	Type of Loading	Concrete Strength (PSI)			Minimum Fastener Spacing
				2000	3000	4000	
Low Velocity	1/8"	3/4"	Pullout Shear	93 152	121 168	147 186	2½"
	9/64"	1"	Pullout Shear	161 250	207 278	252 306	3"
	5/32"	1¼"	Pullout Shear	242 361	311 402	380 442	3¼"
Standard Velocity	11/64"	1¼"	Pullout Shear	323 370	429 550	409 531	4¼"
	3/16"	1½"	Pullout Shear	455 518	643 781	592 735	4½"

NOTES:

1. Shear and pullout values based on average test results divided by a safety factor of 4. Test data is available from fastener manufacturers.
2. The designer should limit shear load for some steel thicknesses and shank diameters as shown in the following table, where steel bearing capacity may control. Bearing strength based on Bearing Area x 2.1 x 33,000 psi.

ALLOWABLE SHEAR LOAD (Lbs.)			
Shank Diameter	Steel Thickness		
	16 GA.	18 GA.	20 GA.
5/32"	—	—	388
11/64"	—	517	427
3/16"	777	621	466

3. Power driven fasteners should not be located closer than 3" from the edge or the concrete may crack, and the fastener won't hold.
4. A minimum fastener spacing is also recommended to prevent concrete cracking.
5. A concrete slab should be three times as thick as the fastener penetration depth. If too thin, the compressive forces forming at the point can cause the far side of the concrete to break away, resulting loss of holding power.

A fastener driven into a hot-rolled structural steel member holds by the natural tendency of the steel to return to its original undisturbed condition. The holding power of a power actuated fastener set in steel is directly affected by the total contact area between

fastener shank and the steel. An increase in either shank diameter or steel thickness will increase holding power, although shank diameter should not exceed steel thickness.

Suggested shear or pullout design loads for power driven fasteners into hot-rolled structural steel are shown in the following table.

SUGGESTED DESIGN SHEAR OR PULLOUT LOADS (lbs.)
FOR POWER DRIVEN FASTENERS IN STRUCTURAL STEEL

Steel Thickness Gage	1/8" Dia. Shank			5/32" Dia. Shank			3/16" Dia. Shank		
	Steel Thickness*			Steel Thickness*			Steel Thickness*		
	1/4"	3/8"	1/2"	1/4"	3/8"	1/2"	1/4"	3/8"	1/2"
	(lbs.)			(lbs.)			(lbs.)		
12	375	500	625	475	650	825	575	800	1000
14	375	500	625	475	650	808	575	800	970
16	375	500	518	475	647	647	575	777	777
18	375	414	414	475	517	517	575	621	621
20	310	310	310	388	388	388	466	466	466

* Hot Rolled Structural Steel

NOTES:

1. Shear and pullout values based on average smooth shank fastener test results divided by a safety factor of 4. Knurled shanks would increase pullout values shown. Test data available from fastener manufacturers.
2. Tests conducted with the point driven completely through the back side of the hot-rolled steel member. This is necessary to obtain proper gripping force.
3. Fasteners should not be located less than ½" from the edge of steel.
4. A minimum fastener spacing of 1½" is necessary.
5. Bearing strength based upon: Bearing area x 2.1 x 33,000 psi for cold-formed steel.

Expansion anchors in concrete develop holding strength primarily from a compression bond of the concrete to the anchor shank. A hole, the same size as the anchor, is drilled in concrete. The anchor is installed in the hole, and expanded by turning the nut on the shank. A sleeve on the shank expands to provide the compression bond.

The amount of compression increases with increased concrete compressive strength and increased anchor diameter, provided there is adequate embedment depth.

Expansion anchors are used in conjunction with hot-rolled steel plate, angles or channel to supplement bearing capacity of cold-formed steel framing.

Suggested design shear and pullout loads for various size anchors are listed in the following table.

SUGGESTED DESIGN LOADS FOR EXPANSION MASONRY ANCHORS
Allowable working values in stone aggregate concrete (lbs.)

Anchor Dia.	Minimum Embedment	Type of Loading	Concrete Strength (PSI)			Minimum Anchor Spacing	Minimum Edge Distance	Minimum Slab Thickness
			2000	3000	4000			
1/2"	2¼"	Pullout Shear	1396 2566	1746 2566	2443 2566	5"	2½"	3¼"
5/7"	2¾"	Pullout Shear	2356 3733	2946 3733	4123 3733	6¼"	3⅛"	4"
3/4"	3¼"	Pullout Shear	3173 5600	3966 5600	5553 5600	7½"	3¾"	4¾"
1"	4½"	Pullout Shear	5066 7333	6333 7333	8866 7333	10"	5"	6½"

NOTES:

1. Shear and pullout strength based on average test results divided by a safety factor of 4. Test data is available from anchor manufacturer.
2. Designer should calculate bearing strength of the material being connected for comparison to the shear loads shown. Bearing strength of steel: Bearing Area x 2.1 x F_y.
3. Minimum spacing, edge distance and slab thickness as noted in the table is necessary.

WELDING

For any structural member to perform to its design capacity, it is critical that strong, uncomplicated, economical connections be used to secure it.

Welding is widely accepted as being the best, the most economical and the most practical way to join steel to steel. Overlapping of pieces being joined is not necessary, and the thickness of the weld area can be held to the thickness of the member to either side.

Welding Processes

There are more than 40 methods for joining metals by fusion, with or without the help of added metal. Of these methods, four lend themselves to the fastening of light gage steel framing components. They are Shielded Metal – Arc Welding (SMAW); Gas Metal – Arc Welding (GMAW); Resistance Spot Welding (RSW); and Resistance Projection Welding (RPW). The first two are fusion welds, and the remaining two are resistance welds.

Fusion Welding

1. SMAW is an arc-welding process wherein the arc supplies the heat needed to melt the base metal surfaces being joined and the filler metal, which then fuse together. The filler metal is provided by a consumable coated electrode which establishes the arc and gradually melts away, filling the joint. The shielding is accomplished by the melting of the coating on the electrode. Recommended filler metals for the SMAW process are:

AWS E-6012 or AWS E-6013 (Mild Steel Electrode)
AWS E-Cu Al - A_2 (Aluminum - Bronze Electrode)
AWS E-Cu Si (Silicon - Bronze Electrode)

The equipment required for SMAW (stick welding), consists of a 200 amp. "hot box" electric welder. A welder like this requires 220-volt electrical service and costs approximately $150.

2. GMAW is an arc-welding process in which the arc is shielded by a chemically inert gas, such as Argon or CO_2. This process is often called inert-gas welding for short; or, more specifically, when a consumable metal electrode is used, metal inert-gas welding (MIG). In MIG welding, the electrode is mechanically fed into the arc. This type of welding is most economical for shop conditions. Recommended filler metals for GMAW are:

AWS E-7014 (Mild Steel Electrode)
Use CO_2, Argon-oxygen, or Argon-CO_2 shielding.
AWS R-Cu Al - A_2 (Aluminum - Bronze Electrode)
Use Argon gas.
AWS R-Cu Si - A (Silicon - Bronze Electrode)
Use Argon gas.

For GMAW (MIG welding), use a wirefeed welder with a capacity of 60-110 amps. and approximately 23 volts variable output. A welder like this requires 220-volt, three-phase electric service and costs approximately $1,800.

Resistance Welding

1. RSW is a resistance welding process wherein fusion is accomplished by clamping the parts to be joined under pressure using the electrodes. Current is then passed through the electrodes and fusion occurs due to the heat generated by the resistance of the metal to the electrical current. The size and shape of the individual welds are limited primarily by the size and contour of the electrodes and by the magnitude of the welding current.

2. RPW is a resistance welding process in which fusion occurs using the same principle as in RSW. The difference in these two processes lies in the fact that in RPW projections or embossments are pre-set into the base metals being joined and fusion occurs when the pieces are clamped together and charged with the electric current. RPW is mostly for shop fabrication and should conform to "Recommended Practices for Resistance Welding, Coated Low-Carbon Steels, AWS Cl. 3-70".

Recommendations

GMAW is the most preferable process for shop fabricating for these reasons: no slag build-up, cleaner, faster, with no need to continually replace electodes. It is also easier on the welder. Stick-welding (SMAW), while the most popular for field use, has some disadvantages. The heat is hard to control and requires constant adjustment as job and weather conditions change. Another drawback is a slag build-up which must be chipped away in order to inspect the weld quality.

Resistance welding (both RSW and RPW), has proven to be largely unsuccessful. In resistance welding, the electrodes must come in contact with base metals for the electrical current to flow. Any surface finish on the metal, such as red-oxide paint or galvanizing, prevents the electrodes from making proper and secure contact, resulting in a poor weld.

The coating on steel does not effect the weld quality in fusion welding; however, care should be taken when welding galvanized materials to provide adequate ventilation.

Design of Welded Connections

The purpose of any connection is to permit the structural member being joined to perform to its ultimate capacity. Therefore, all connections should be designed to transmit the maximum stress in the connected member with proper regard for eccentricity. If members are subject to reversals in stress, except if caused by wind or earthquake loads, the connection should be designed for the sum of the stress. Connections subject only to stresses from wind or earthquake loads may be portioned for stress 33-1/3 percent greater than those specified for dead and live load stresses, in accordance with A.I.S.I., Section 3.1.2.1.*

The American Welding Society (AWS) has published a chart of standard welding symbols. The information provided there requires an understanding of basic engineering fundamentals. It is important, therefore, that the design of structural connections be left to the Project Engineer.

Fusion Welds

The types of fusion welds generally used for connecting light gage steel framing components to each other, or to hot-rolled structural components, are fillet welds, butt welds, plug welds and arc-spot welds (puddle welds).

Fillet welds and plug welds are suitable whenever the metal being joined is lapped. With fillet welds, if the weld is parallel to the direction of the applied force, it is longitudinal; and if it is perpendicular, then it is transverse. Transverse welds are stronger, per inch of weld, than longitudinal welds because they are more uniformly stressed along the entire length plug welds are circular fillet welds where one of the base metals is prepunched to accommodate the weld. The strength of plug welds, per inch of weld (the length of the plug weld is considered to be the perimeter of the hole), is close to that of transverse welds.

** Sections mentioned here and later from A.I.S.I. are taken from the A.I.S.I. Cold-Formed Steel Design Manual – Part I "Specification for the Design of Cold-Formed Steel Structural Members", 1968 edition.*

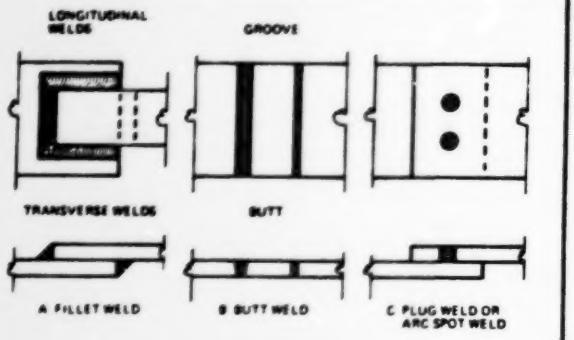


Figure 4 – Types of Fusion Welds

Fillet welds and plug welds should be positioned so that they are subject to shearing stress only. The allowable shear may be computed by multiplying the allowable weld shear stress by the throat area of the weld. However, the throat thickness dimension shall not exceed the thickness of the thinnest member being connected. Permissible shear stress values for fusion welds are given in A.I.S.I., Section 4.2.1.

Allowable shearing force per inch of weld based on full thickness penetration are as follows:

Design Thickness(t)	Throat Area 0.707 x t x 1"	Weld In Shear (Lbs. Per Lineal Inch)
.0478	0.0339	460
.0598	0.0420	570
.0747	0.0530	720
.1046	0.0707	960

Butt welds are considered to be as strong as the lower grade or base metals being joined for both tension and compression stress. This is provided the weld penetrates 100 percent of the section and the yield strength of the filler metal meets or exceeds the yield strength of the base metal. Stresses due to eccentric loading should be combined with the primary stresses.

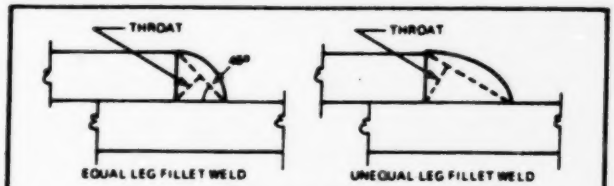


Figure 5 – Cross section of Fillet Welds

Resistance Welds

In the design of resistance welds, both spot and projection welding are used mostly for shop welding with light gage steel framing. Permissible shear strength per spot weld is given in A.I.S.I., Section 4.2.2, and is based on AWS "Recommended Practices for Resistance Welding."

Spot welds should only be used where the weld is subjected to shear stresses. The allowable shear per spot weld shall be as follows:

Thickness of Thinnest Outside Sheet, In.	Allowable Shear Strength per Spot, kips	Thickness of Thinnest Outside Sheet, in.	Allowable Shear Strength per Spot, kips
.010	0.050	.080	1.075
.020	0.125	.094	1.375
.030	0.225	.109	1.65
.040	0.350	.125	2.00
.050	0.525	.188	4.00
.060	0.725	.250	6.00

(The above values are based upon "Recommended Practices for Resistance Welding", C1.1-66, American Welding Society, 1966 and apply to pulsation welding as well as spot welding.)

If tensile strength of spot welding is required, it can either be obtained from tests or from empirical formulas for tensile and shear strengths proposed by Henschkel.**

** *See Henschkel, J.: "The Expression of Spot-Weld Properties," Welding Journal, October, 1952.*

OTHER FASTENING SYSTEMS

While we recommend welding as the safest – and most economical – method of assembling steel framing components, there are other methods available, particularly for the attachment of collateral materials.

1. **Bolts.** Steel studs and joists are not pre-punched with fastener holes, threaded or unthreaded. As a result, nuts and bolts aren't generally used with this system. The major exception would be anchor bolts employed to fasten stud tracking to concrete foundations or floors.
2. **Screws.** Self-tapping screws can be an alternative to welding for some jobs. You will want to follow the recommendation of the framing manufacturer – in consultation with the architect – in using this system. While not always ideal for assembling the frame itself, screws are the most common way of attaching collateral materials. In one motion, the screw drills its own hole and securely fastens metal, wood, drywall, decking, facings, lath, electrical and mechanical components, and clips and accessories to the steel framing and to other structural members of the system.

   Doing the job are hand-held screw guns that operate at 2,500 RPM on 115-volt power. Screws come in a variety of head styles to fit the total range of requirements . . . with zinc or cadmium plating to meet the needs of the application environment . . . screws are also available with sealing washers to resist moisture and corrosive atmospheric conditions.
3. **Nails.** Spiral-shank nails – case hardened and phosphate treated to etch their surface for increased holding power – are used predominantly to fasten plywood subfloors to the top flange of the steel joist. (After the nails pass through the wood and penetrate the flange, the screw threads make a quarter turn to cut a partial thread in the pierced steel, firmly connecting subfloor and joist.) Nails are also employed to fasten materials to nailable studs and joists, which consist of two rolled channel sections welded back to back, with nailing grooves for attachment of collateral materials.
4. **Adhesives.** Adhesives are optional when self-drilling screws are used in attaching plywood to steel joists, but are recommended when hardened screw-shank nails are employed for this application. With either fastening method, the long-term bonding efficiency of construction-type adhesives contributes to stable, non-squeaking floor assemblies, and acts as an acoustical insulator. Adhesives are also utilized in attaching drywall materials and paneling to steel studs, serving to eliminate some but not all of the need for mechanical fasteners.
5. **Power Driven Fasteners.** Powder-actuated fastening tools

use .22 or .23-caliber cartridges to provide the power load. For safety reasons, select a force-entry tool in which the power load cannot be fired unless the tool is first pressed firmly against the track web.

Correct fastener penetration is obtained by matching the energy level to the job. In the low-velocity model of this power tool, the force of the power load acts on a central piston which drives the fastener. In the standard-velocity model, the power load acts directly on the fastener head to drive it through the steel and into the concrete. The velocity of the fasteners can be changed to suit material densities by proper load selection and/or placing the fasteners at different depths in the barrel bore.

Usually used for attaching wall track to concrete slab.

6. Wire Ties. Wire tying is sometimes acceptable for attaching metal lath to framing components, but should never be used for joining framing components in load-bearing or curtainwall applications.

B. CONSTRUCTION DETAILS

1. General Guidelines
2. Floor Systems
3. Wall Systems
4. Roof Systems
5. Bridging & Bracing Details

THE ADVANTAGES OF STEEL FRAMING SYSTEMS

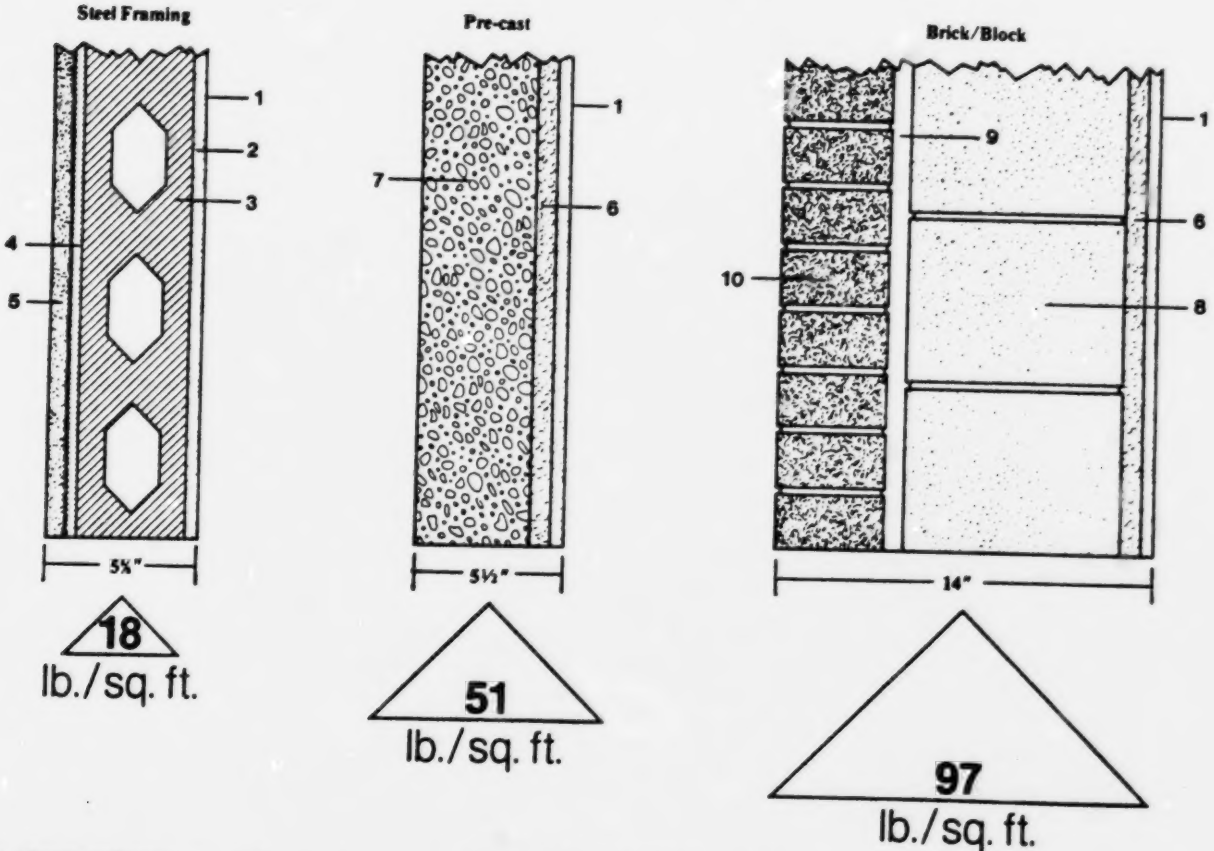
WEIGHT

As illustrated by the sketches, the weight of a steel framed exterior wall is *considerably less* than other systems.

Because the structure must support the exterior wall, reduced weight means less structure cost.

The building's exterior beams, or spandrel beams, are most affected by wall weight. To a lesser degree, but also important, column and footing size may be affected.

An example of the impact can be illustrated by comparing 4" solid precast concrete with a light weight cavity steel-framed, concrete finish wall. With a 10 foot floor-to-floor dimension, the weight applied to the exterior beam would be 510 lbs. per lin. ft. vs. 180 lbs., or a difference of 330 lbs. for each lineal ft. of wall.



1. Gypsum wallboard
2. R-11 Cavity Insulation
3. Steel studs
4. Gypsum sheathing
5. Concrete finish on metal lath
6. Polystyrene insulation (1")
7. 4" solid precast
8. 8" concrete block
9. Air space
10. 4" brick

If columns are spaced 30 feet on center, the *difference* in load on *each* column at *each* floor would be 9,900 pounds.

If the building is ten stories high, the *difference* in load applied to each exterior footing would be 99,000 pounds.

Weight is of even greater importance in seismic zones. Seismic design forces, and resulting bracing requirements, are directly related to total building weight. Thus, lightweight steel framed systems can reduce required bracing and the related cost.

framed exterior walls with other systems, there is little doubt as to which system best reduces energy loss.

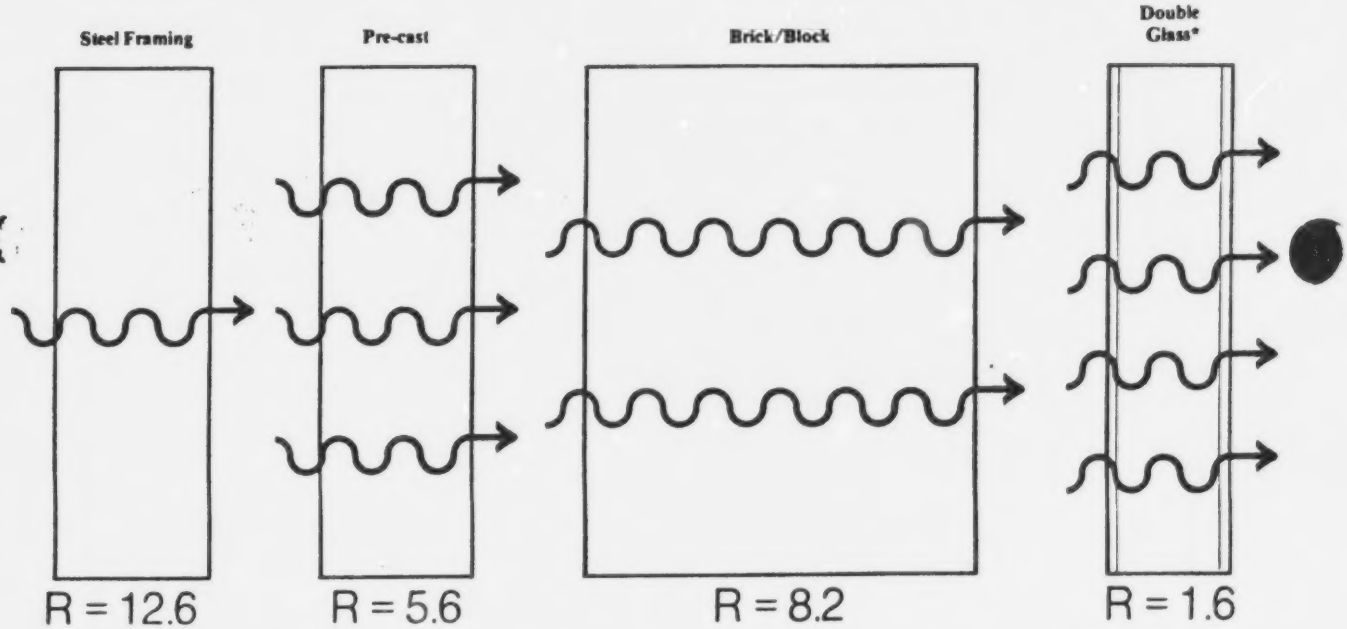
The energy transmission through a wall is directly related to the resistance (R) provided by the construction. Increasing the "R" value, or resistance, means less heat will be transmitted. Whether interior heat loss in a cold climate, or interior heat gain for an air-conditioned building in a warm climate, the need is the same.

Compare the thermal resistance (R) values for these assemblies described in detail on the previous page.

THERMAL TRANSFER — ENERGY SAVINGS

Energy conservation plays a large part in our world, and it's a concern that all of us share. In comparing steel

Occupants, owners and builders all look for increased thermal resistance which permits lower initial construction cost due to a reduction in heating and/or air conditioning equipment requirements. Improved thermal resistance also reduces operating cost.



* Double ¼ " glass with air space.

"R" values calculated considering all materials in the wall construction plus exterior and interior air film factors. Individual values obtained from the Heating, Ventilating, Air Conditioning Guide published by the American Society of Heating and Air Conditioning Engineers.

SPEED OF ERECTING

The majority of owners, developers and construction managers relate construction time with construction cost. Construction financing is expensive, consequently its time duration must be kept to a minimum. Everyone concerned with financing a project is also well aware that return on investment doesn't start until the building is completed and occupied.

Steel framed systems permit considerable improvement in construction speed.

Steel framing is frequently pre-fabricated. With ad-

vance production of complete panel assemblies, wall, floor, and roof framing installation time is greatly reduced when compared to conventional piece-by-piece construction.

Whether load-bearing or curtainwall construction, consider the installation time required for a steel framed system as compared to brick and block for an 8 ft. by 12 ft. area. A pre-fabricated or pre-finished panel can be erected in a matter of minutes. A masonry wall of these dimensions would require more than 280 pieces of brick and over 100 pieces of block.

The advance fabrication may be accomplished in a temporary shelter at the site, or in the contractor's shop. Thus, delays due to adverse weather conditions are greatly reduced.

Another important consideration for many owners is the fact that completed panels can be erected in below freezing temperatures. This factor essentially permits year-round construction in all areas of the country without time delays.

NON-COMBUSTIBLE — HIGH STRENGTH

Steel framing is non-combustible. Consequently, fire and comprehensive insurance costs are reduced in comparison with combustible wood framing.

The advantage of steel over wood framing is significant when comparing axial load capacity.

A C-stud, size 3⅝" by 16 gage, can sustain an axial or column load more than double the capacity of a 2 x 4 wood stud.

This difference enables steel studs to be placed 24" on-center vs. the need for 16" on-center spacing with wood studs.

With increased capacity, steel stud framing is able to support four and five story buildings. This factor becomes increasingly important, especially to multi-family builders, as land costs rise. Building codes and strength capacity normally limit combustible wood frame structures to three stories. An additional height of one or two floors permits greater density with less property area. Some projects have been economically feasible because of this consideration.

Floor and roof joists of high strength steel are also normally spaced 24" on-center. In addition, they have capacity for longer spans, reducing the number of bearing walls and permitting greater flexibility for the designer.

Non-combustibility, fewer pieces, greater capacity and longer spans are important considerations. Of equal importance, there are no shrinkage, warping, swelling or nail-pop problems with steel framing.

FIRE AND SOUND RATINGS

Numerous steel framed assemblies have been rated for fire endurance, airborne sound transmission and impact noise insulation. Fire and sound ratings are dependant upon the facing materials attached to the framing, in make-up of a complete assembly.

Many one and two-hour fire endurance ratings are available for both wall and floor-ceiling constructions. Fire ratings up to four hours are also available for wall assemblies using proper selection of collateral materials.

In addition to specific sound transmission ratings, the American Iron and Steel Institute has published the brochure *"Steel Framing Components Found Acoustically Effective by NAHB Research Foundation."* Those studies verify that steel joist construction performs equally to wood joists, and steel stud framed walls are equal to wood framed walls with the same collateral material.

Copies of that brochure, and specific fire rating test result information to accommodate the designer's criteria may be obtained from ML/SFA manufacturers.

ADVANTAGES OF PRE-PUNCHING

The cost for installation of electrical and plumbing utilities is lower with steel studs because they are pre-punched. There is normally no need for cutting holes, as would be required for wood studs. Of even greater consequence is the comparison between pre-punched steel studs and masonry construction, where openings in the block must be cut in the field, or furring attached over the face of the block to permit installation of utilities.

CHOICE OF FACING FINISH

The exterior of a building is its most prominent feature—the first criterion upon which the validity and coherence of its architectural design are judged. And, since the completed structure is continually exposed to public view, judgments are passed on its appearance every day for as long as it endures.

Surface treatment has an important influence on the over-all effect achieved. For that reason, the architect is deeply concerned over the selection and use of exterior surfacing materials that exactly fit and aesthetics of the design.

With steel framing back-up, the architect has little

difficulty in finding exterior surfacings that are "right" for the building. The diversity of materials, shapes, textures, colors and finishing techniques at the designer's disposal are almost unlimited.

The opportunity to use combinations of materials, textures and colors gives the architect freedom of expression.

Steel framed systems may be used on buildings of any shape. They are readily adapted to flat or curved surfaces, angles, recesses or projections.

The walls constructed with these systems may be either load bearing or non-load bearing. They are applicable to most requirements of both low rise and high rise structures.

Steel framed systems are versatile. They provide ample bearing and attachment surface for a wide range of facings and finishes.

From a variety of cementitious finish selections, the designer may provide the appearance of massive, solid concrete, at a fraction of the weight. The exterior surface may have a smooth, textured, aggregate or some type of architectural finish.

Other common exterior finishes include brick veneer, pre-finished plywood, pre-finished steel siding, split-block veneer, stone veneer, architectural aluminum composite facing materials, and the list goes on.

Construction Details

Residential framing details can be conveniently organized into three distinct catagories: floor, wall and roof systems. In addition to understanding these structural classifications or "diaphragms" it is important to examine the means of connecting the systems.

Many construction similarities exist between wood and light metal framing systems within the standard applications that are illustrated. This similarity makes the transition from wood to steel framing a relatively simple one.

Types of Framing

Floors

The galvanized steel component known as the structural cee is the predominant shape used for floor joists. Generally, builders opt for a web depth ranging from 6" to 12" with a steel thickness from 12 gage to 18 gage. The strength of steel allows wider spacing between joists and longer spans, a feature that makes for increased design flexibility and decreased material, labour costs.

Walls

For structural or load bearing walls the structural cee, punched channel or I-channel shapes are used. These generally are not less than 3½" in web depth, and usually fall within the weight range of 16 gage to 20 gage. The I-channel or so called "nailable" stud has lost much of its popularity in recent years, as builders increasingly turn to the more versatile, screwable structural cee.

For interior partitions, applications are best handled with the standard cee stud. Since this is not a load bearing application, thinner steel members can be used, generally in the 20 gage to 25 gage range. Narrower web depths are the norm, ranging from 15/8" to 6".

Roofs

The workhorse of galvanized steel framing, the structural cee, is the predominant shape used for roof rafters and ceiling joists. Rafters usually have a web depth of 6" to 12", with gages ranging from 12 to 18. Ceiling joists can be designed in smaller sizes to save on cost, due to the lighter loads normally involved.

Sheet Metal Gage

What is a Gage?

A steel producer typically rolls sheet steel in a broad range of thicknesses, with only small thickness differences among consecutive sizes. Accuracy for sheet steel specifications, therefore, requires that the thickness be represented in decimal equivalents of an inch (to as many as five places). Since dealing with such numbers can become tedious, and the possibility of error great, a system of corresponding whole numbers was developed to simplify the specification of sheet steel. This simplified numeric designation, called the gage, is commonly used by designers and builders in order to identify the required thickness of sheet steel used in steel framing components.

Table 4a. illustrates the relationship of the gage number and its respective thickness, for galvanized sheet steel. Thus, the thickness, shown in inches, includes the zinc coating. To obtain the thickness of the base metal, refer to ASTM standard A446. The weight in pounds per square foot of zinc-coated sheet steel is also shown.

How is sheet metal formed?

All of the components represented in Sections 2A and 2B are cold-formed shapes. While a typical wood member (i.e., a 2x4) is rough-sawn from a tree and planed to its finished surface condition, a cold-formed shape is produced by running lengths of coiled sheet steel through a machine which performs the bending required for the finished shape.

The major structural characteristics of any cold-formed shape depend on the shape the sheet is to take and the physical qualities of the sheet steel from which it is formed. Two qualities are important to the strength of a cold-formed shape, yield strength and gage. Most manufacturers inventory sheet steel at two minimum yield strengths, with 33,000 psi, 37,000 psi, 40,000 psi, or 50,000 psi among the most common. In addition to a selection of yield strengths, most manufacturers carry sheet steel in a variety of gages. This variety of yield strength and gage enables the designer to specify just the right kind of sheet steel for each application.

To simplify your job as a builder, the manufacturers of steel framing components have already identified the appropriate gage and strength for various structural components. This information appears in the manufacturers brochures which follow.

Table 4a.

Gage No.	Thickness Equivalent in inches	Weight lb/ft²
8	0.1681	7.03125
9	0.1532	6.40625
10	0.1382	5.78125
11	0.1233	5.15625
12	0.1084	4.53125
13	0.0934	3.90625
14	0.0785	3.28125
15	0.0710	2.96875
16	0.0635	2.65625
17	0.0575	2.40625
18	0.0516	2.15625
19	0.0456	1.90625
20	0.0396	1.65625
21	0.0366	1.53125
22	0.0336	1.40625
23	0.0306	1.28125
24	0.0276	1.15625
25	0.0247	1.03125
26	0.0217	0.90625
27	0.0202	0.84375
28	0.0187	0.78125
29	0.0172	0.71875
30	0.0157	0.65625
31	0.0142	0.59375
32	0.0134	0.56250

*Source: *Building Construction Handbook*, Frederick S. Merritt, McGraw-Hill Book Company, 1975

Floor Design

General Design Practices

1. Minimum Bearing of Joist at Supports:
   a. 1½" on wood or metal sill with end bearing condition.
   b. 4" on masonry with end bearing condition.
   c. 2" on wood or metal ledger with end bearing condition.
   d. 4" overlap of joists over interior bearing with simple span condition. (maximum of 12")
   e. 20" overlap of joists over interior bearing with continuous span condition.

2. Multiple Joist Condition Minimums:
   a. Doubled joists under and parallel to bearing partitions.
   b. Doubled joists surrounding an opening when dimension of the opening perpendicular to joist span exceeds 4 feet.

3. Solid Blocking Conditions:
   a. Within each joist set where joists bear across supporting structure.
   b. 4 feet on center between end joist and first parallel joist (first and last joist bays).
   c. At intermediate points within floor span as opposed to bridging.
   d. Minimum blocking member relative to floor joist as follows:
      for. 6" joist, use 3⅝" (D) x ¾" (F) x 16 ga. unpunched channel.
      8" joist, use 4" (D) x ¾" (F) x 16 ga. unpunched channel.
      10" joist, use 6" (D) x ¾" (F) x 16 ga. unpunched channel.
      12" joist, use 6" (D) x ¾" (F) x 16 ga. unpunched channel.

4. Bridging Requirements for Lateral Support:
   a. Spacing of bridging as per Table 4b.
   b. Standard sizing and schedule as per Table 4c

5. Limitations on web holes which are site cut:
   a. Unreinforced web holes: (6" joist min.)
      —Maximum opening of 2½" diameter or 2½" x 4" oval centered on web
      —Minimum spacing of 18" on center, with 20" minimum to the edge of a supporting structure.
   b. Any joist with an unreinforced web hole over a bearing point must be reinforced with a web stiffener.
   c. Reinforced web holes: (6" joist min.)
      —12 ga. reinforcement plate will allow maximum hole diameter up to 2" less than web depth, 18" on center minimum.
      —14 ga. reinforcement plate will allow maximum hole diameter up to ½ of web depth, 18" on center.

Table 4b

Joist Span	Spacing of Bridging
up to 14'	one row at midspan
14' to 20'	two rows at ⅓ span
20' to 26'	three rows at ¼ span
26' to 32'	four rows at ⅕ span
over 32'	every 8'-0" on center

Table 4c

Schedule	Bridging Member
a. First and last two joist bays	Solid Blocking (item 3)
b. Next five bays continuous	2" wide, 16 ga. strapping top and bottom
c. Next single bay	Solid Blocking

Repeat b and c.

The above data has been provided for comparative purposes only and must not be used for design. Consult manufacturers' data for design values and specifications.

Floor Design

General Design Practices (cont.)

6 Allowable Span of Floor Joists:
Table 4d illustrates maximum allowable spans for floor joists. It is a *generic* representation of the typical floor joists manufactured within the industry and is intended only for comparison to wood members. The top number in each category indicates the limit in feet for simple span conditions. The bottom number shows the limit for continuous span conditions (note that this condition may require a web stiffener at midspan). The deflection is limited to L/360. The specifications of individual manufacturers must be researched prior to inclusion in final designs.

Table 4d

Joist		Load Conditions								
		10# DL + 20# LL = 30# Total Load			10# DL + 30# LL = 40# Total Load			10# DL + 40# LL = 50# Total Load		
Size (nominal)	Spacing (inches)	14 Gage	16 Gage	18 Gage	14 Gage	16 Gage	18 Gage	14 Gage	16 Gage	18 Gage
2x6	12	20.0	18.5	17.0	17.5	16.0	15.0	15.5	14.5	13.5
		26.5	25.5	18.5	23.0	21.5	16.0	21.0	19.5	14.5
	16	18.0	16.5	15.5	15.5	14.5	13.5	14.0	13.0	12.5
		24.0	22.0	16.0	21.0	19.0	14.0	19.0	17.0	12.5
	24	15.5	14.5	13.0	13.5	12.5	11.5	12.5	11.5	10.0
		20.0	18.0	13.0	17.0	15.5	11.5	15.5	14.0	10.0
2x8	12	25.5	23.5	22.0	22.0	20.5	19.5	20.0	18.5	17.5
		33.5	31.5	23.0	29.0	27.5	20.0	26.5	24.5	18.0
	16	23.0	21.5	20.0	20.0	18.5	17.5	18.0	17.0	15.5
		30.5	27.5	20.0	26.5	23.5	17.5	23.5	21.0	15.5
	24	20.0	18.5	16.5	17.5	16.0	14.0	16.0	14.5	12.5
		24.5	22.0	16.5	21.5	19.0	14.0	19.0	17.0	12.5
2x10	12	29.0	27.0		25.5	23.5		23.0	21.5	
		32.5	30.5		28.5	26.5		26.0	24.0	
	16	26.5	24.5		23.0	21.5		21.0	19.5	
		29.5	27.5		26.0	24.0		23.5	22.0	
	24	23.0	21.0		20.0	18.0		18.0	16.5	
		26.0	24.0		22.5	21.0		20.5	18.5	
2x12	12	34.0	32.0		30.0	28.0		27.0	25.0	
		38.5	35.5		33.5	31.0		30.5	28.5	
	16	31.0	28.5		27.0	25.0		24.5	22.5	
		35.0	32.5		30.5	28.5		27.5	25.5	
	24	27.0	23.5		23.5	20.0		21.0	18.0	
		30.5	27.0		26.5	23.0		24.0	19.5	

The above data has been provided for comparative purposes only and must not be used for design. Consult manufacturers' data for [illegible] and specifications.

Floor Design

Comparative Framing Designs (Wood vs. Light Steel)

1. Design Conditions
   a. Framed area, spans, supports and briding locations identical for both wood and steel joist framing
   b. Joists open, with no ceiling below
   c. One stairway framed opening, 3x9 ft
2. Design Criteria
   a. Live Load 40 lb/ft²
   b. Dead Load 10 lb/ft²
   c. Limiting Deflection (live load only) 1/360 clear-span

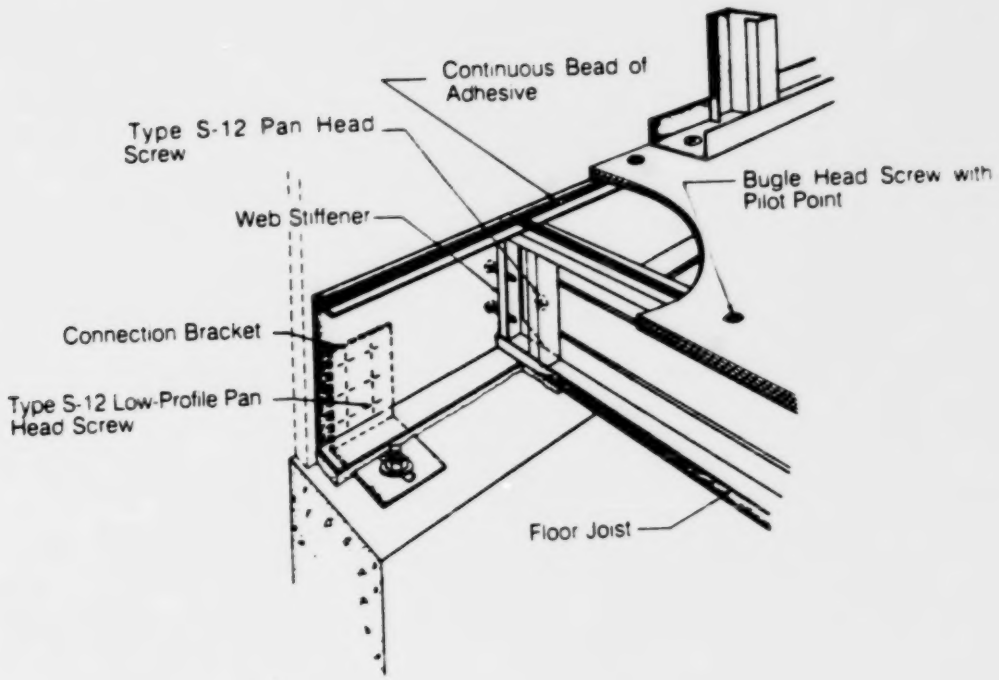
Floor Framing Comparison

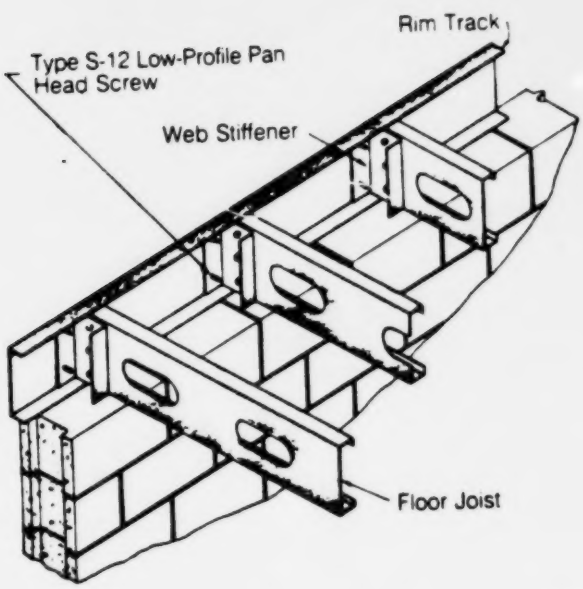
Wood	Framing Item	Light Steel Framing
#2 Kiln-dried Spruce-Pine-Fir 2x10 @ 16"o.c. sgl.-span, lapped 4" over center-beam support, solid blocking over beam, with 16d common wire nails	Joist Size/Spacing/Span Condition	8", 18 ga. structural cee joist @ 24" o.c. full-length, dbl.-span reinforced over center-beam support with 28" joist reinforcement, ¾" Type S-12 Low Profile Pan Head screws
2x6 sill plate, 10d common wire nails (joists), 8d common wire nails (stringer)	Foundation Attachment	Connection bracket @ 6' o.c., ¾" Type S-12 Low Profile Pan Head screws
2x10 header, 16d common wire nails (to joists), 8d common wire nails (to sill)	Joist End Closure	8", 18 ga. rim track, with ¾" Type S-12 Low Profile Pan Head screws to joist web stiffener and from stiffener to joist
10d common wire nails	Joist-to-Center-Beam Attachment	Connection clips, ½" Type S-12 Pan Head Screws
1x3 wood @ mid-span, with 8d common wire nails	Bridging	1½", 20 ga. V-bracing @ mid-span, continuous (with ¾" Type S-12 Low Profile Pan Head screw to ea. joist), plus 4", 16 ga. section for solid blocking every 4th joist spacing (8' o.c., max.) with 2x2x6" connection clips and ½" Type S-12 Pan Head Screws
16d common wire nails for double headers to double trimmers and tail joists	Stairway Framing	Double headers to double trimmers with 8" joist hangers, and to tail joists with 2x2x6" connection clips, both attachments with ⅜" Type S-12 Low Profile Pan Head screws
⅝" t&g plywood, attached with continuous single-bead of adhesive and 6d annular-thread nails to each joist	Subfloor, and Attachment to Joists	¾" t&g plywood, attached with continuous single bead of adhesive and 1⅛" Type S-12 Bugle Head Screws with Pilot Point to each joist and rim track

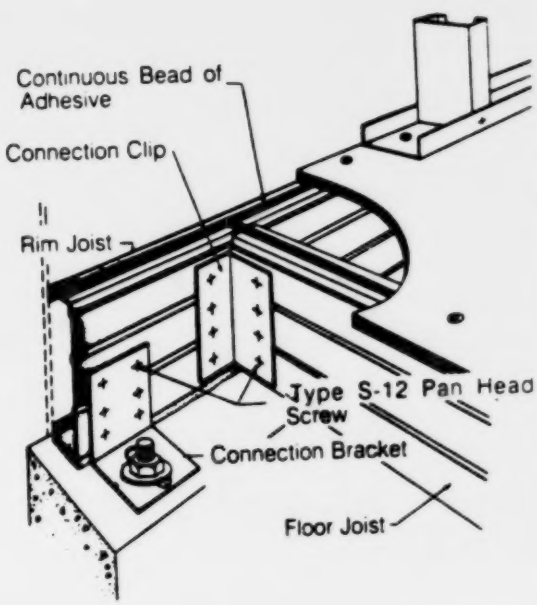
The above data has been provided for comparative purposes only and must not be used for design. Consult manufacturers data for design values and specifications.

Floor at Foundation

Joist to Steel Rim



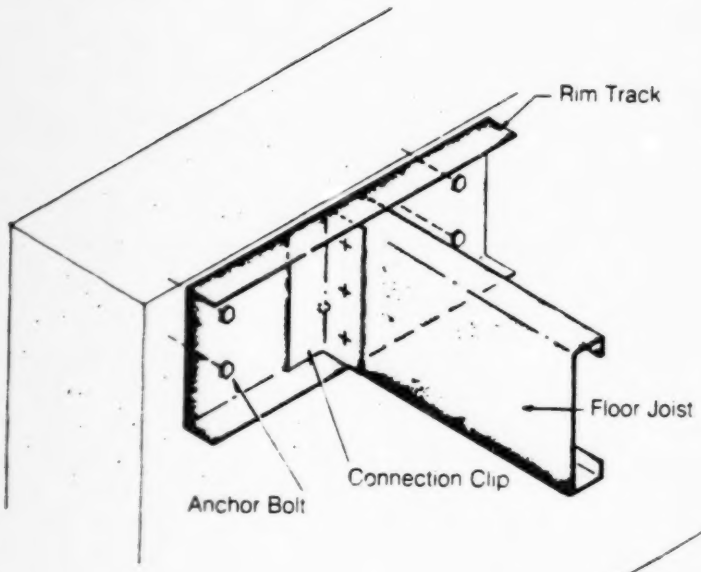


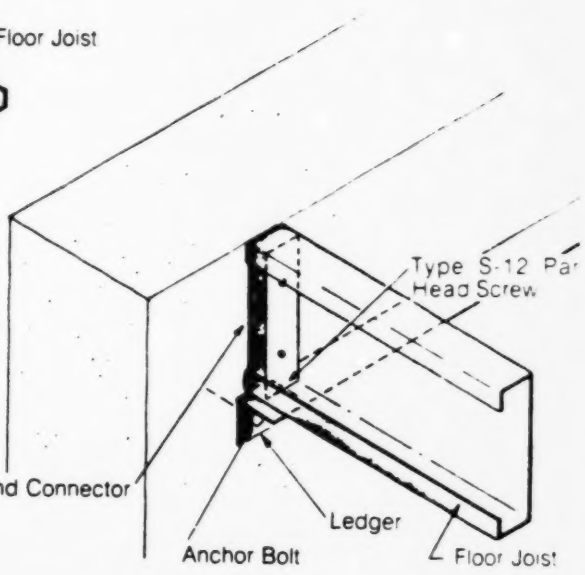


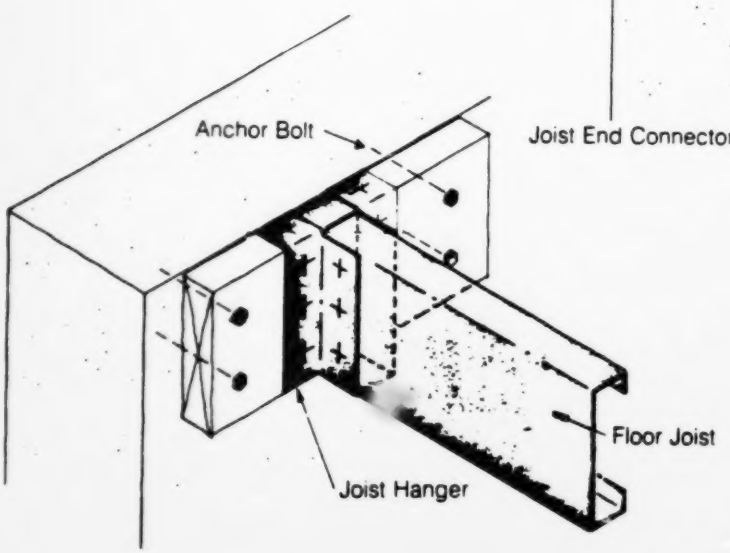
Illustrations courtesy of United States Gypsum Company

Floor at Foundation

Joist on Ledger





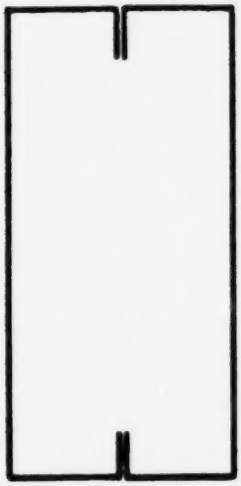


Illustrations courtesy of United States Steel

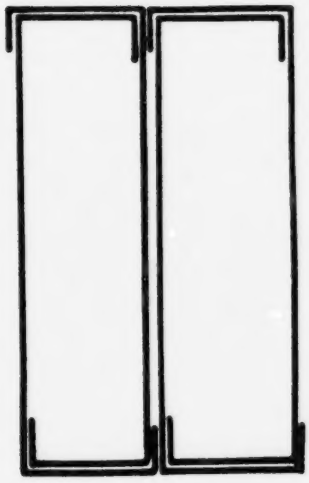
Built-up Beam

Nested
Double

Nested and Single
Triple



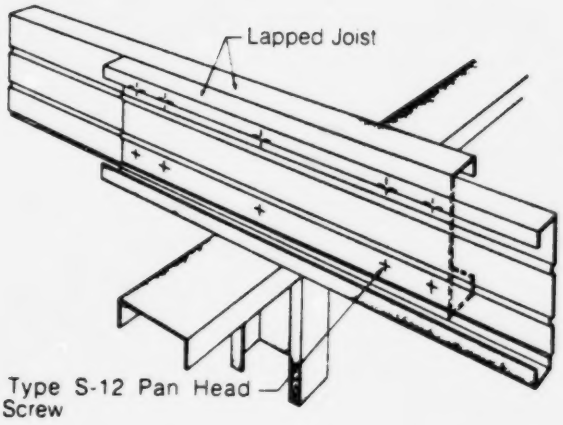
Double

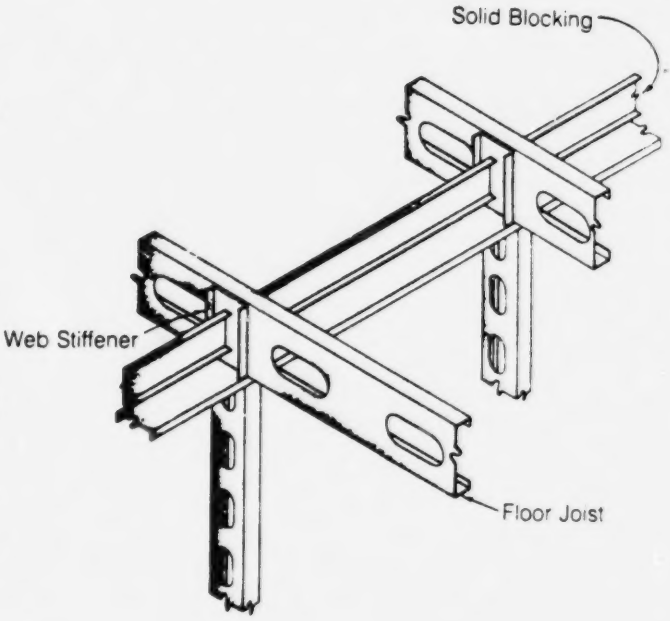


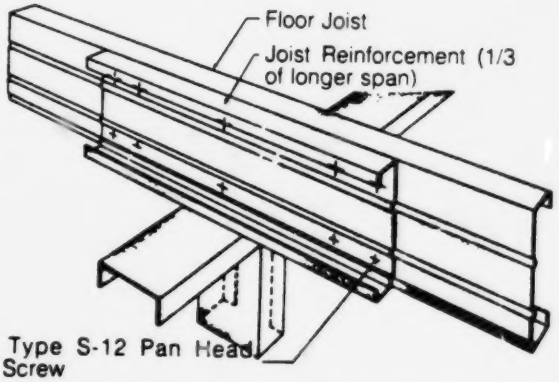
Double Nested

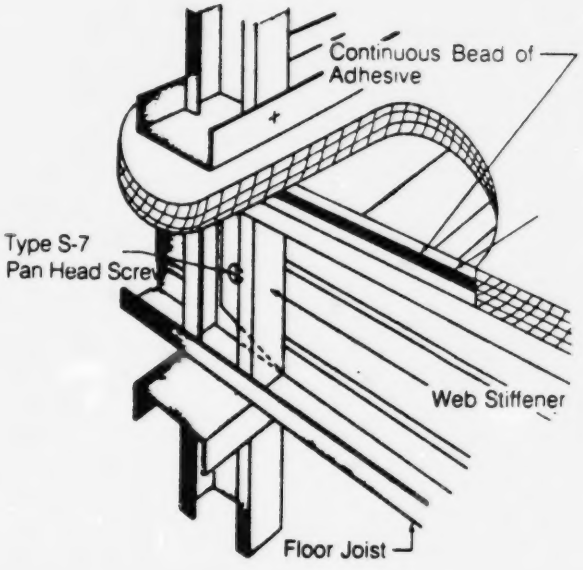
Floor at Interior Bearing

Joists over Bearing Wall; Continuous Span





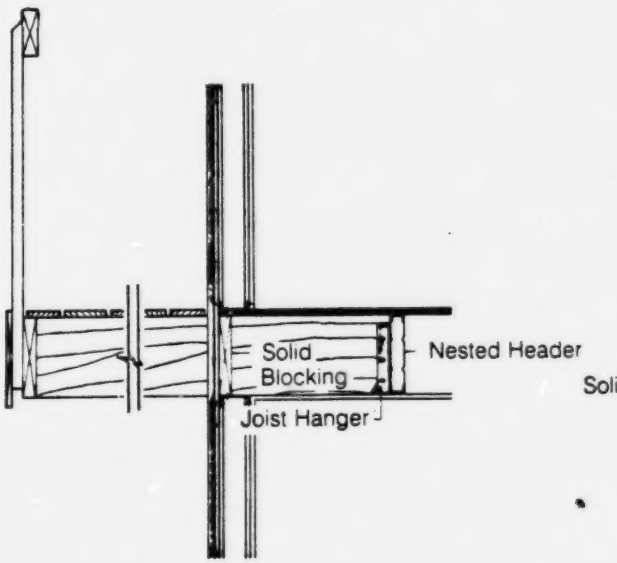


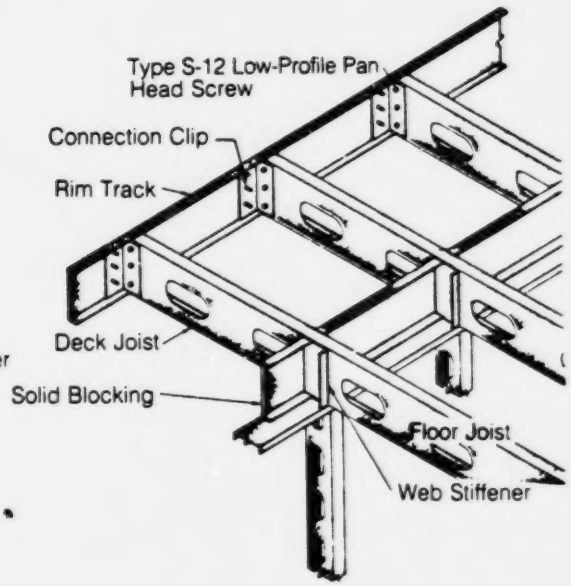


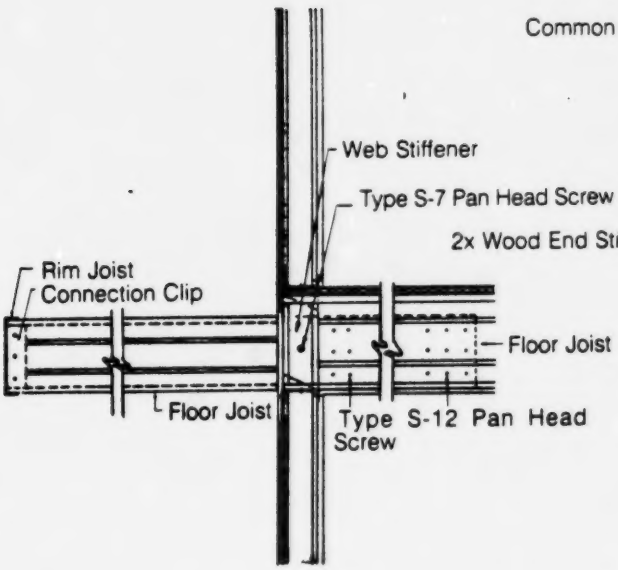
Illustrations courtesy of United States Gypsum Company
Wheeling Corrugating Company

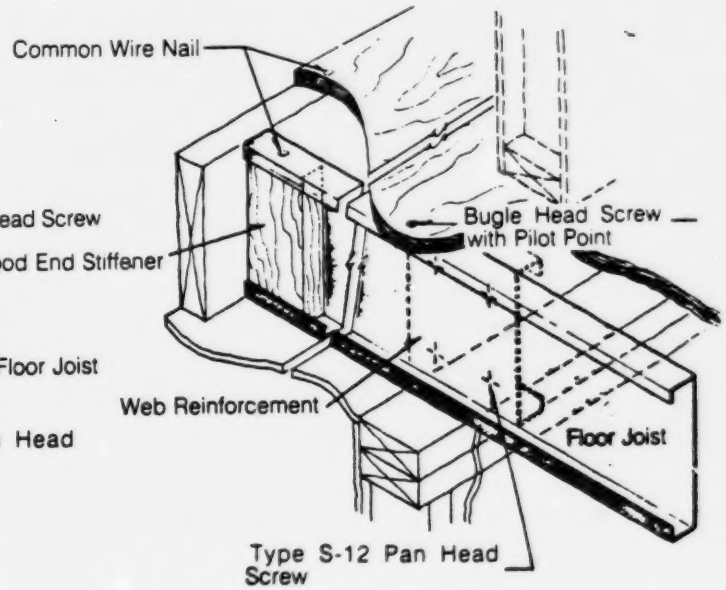
Floor Cantilever

Balcony Cantilever

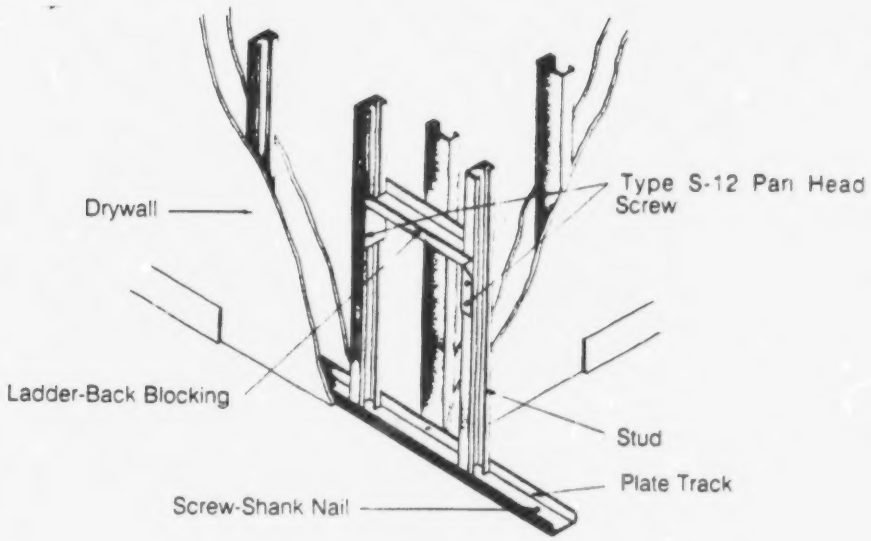


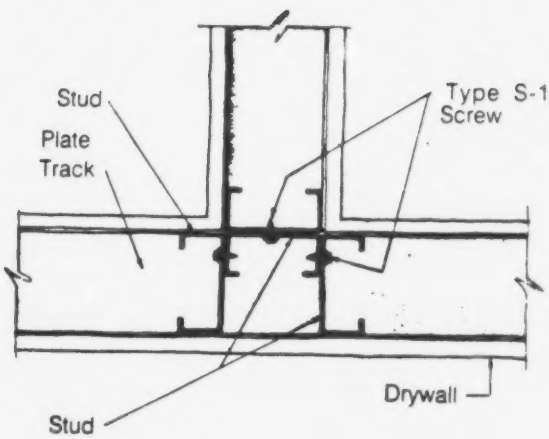


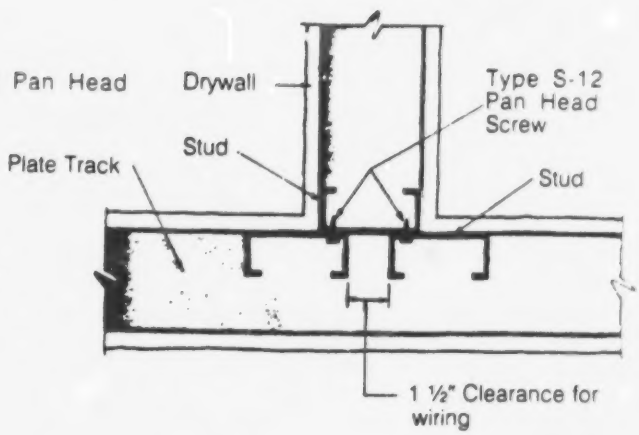




Intersection Details







Wall Design

General Design Practices

1. Minimum Bearing of Stud:
   a. Flanges and web are to be enclosed with the plate track, which is to be secured to a solid base.
   b. As plate track is not a structural member, studs are to be aligned with rafters or joists above and below unless interrupted by an opening (where a lintel is required within the top plate track to disperse the load from above to king studs.)

2. Multiple Stud Conditions:
   a. As required at either side of a wall opening
   b. As required to construct a column to support upper structure.
   c. As required at corners or intersections of walls.
   d. As required at either side of solid blocking for support of wall-hung fixtures and cabinets.
   e. Not less than 3 studs per corner, with strapping across top plate tracks to connect walls.

3. Solid Blocking Conditions:
   a. As required at wall intersections and corners.
   b. As required for attachment of cabinets, shelves and fixtures to walls.
   c. As fire blocking; at 8' vertical intervals, for any wall over 8'.

4. Diagonal Bracing Requirements:
   a. Strapping at not more than 60° nor less than 45° from horizontal.
   b. 48" wide sheathing may be used in place of strapping with thickness of sheathing to be as follows:
      —5/16" plywood for 16" stud spacing
      —3/8" plywood for 24" stud spacing
   c. Diagonal bracing to be applied in each direction at a maximum of every 25' along the length of the wall and as near to each end of the wall as practical.

5. Lateral Bracing Requirements:
   a. Necessary for all load-bearing wall conditions.
   b. Refer to Table 4e for spacing and 4f for sizing.
   c. 16 ga. strapping or 16 ga. v-bar may be used on each side of wall as lateral bracing in lieu of Table 4f.

Table 4e

Stud Height	Lateral Bracing Required
up to 10'	one row at midpoint
10' to 14'	two rows at 1/3 point
over 14'	every 4'-0" o c

Table 4f

Stud Web Size	Type and Size of Lateral Bracing
2½"	¾", 16 ga cold rolled channel
3¼"	¾", 16 ga cold rolled channel
3⅝"	¾", 16 ga cold rolled channel
4"	¾", 16 ga cold rolled channel
6"	1½", 16 ga. cold rolled channel
8"	2", 16 ga cold rolled channel or, 2½", 18 ga un-punched channel

Wall Design

Comparative Framing Designs (Wood vs. Light Steel)

1. Design Conditions:
   a. Framed area, wall pattern, wall height, openings, bracing, interior and exterior wall finish materials, identical for both wood and steel stud framing.
   b. Two-story structure with interior partitions in both non-load and load bearing capacity.

2. Design Criteria: (per Table 4g.)
   a. 3⅝" wall cavity
   b. 8'-0" wall height
   c. 24" on center stud spacing.
   d. wall deflection on second level = 1/240, on first level = 1/360.
   e. 25 psf wind load
   f. second floor loading of 40 lb/ft² live, 10 lb/ft² dead
   g. roof loading of 40 lb/ft² live, 10 lb/ft² dead

Wall Framing Comparison

Wood	Framing Item	Light Steel Framing
Stud grade, kiln-dried Spruce-Pine-Fir 2x4 @ 24" o.c., double top plate, 1x4 diagonal let-in windbrace, and 16d nails.	Second Floor Sidewalls (Taking wind and roof loading)	1⅝" x 3⅝" 18 ga. structural cee stud @ 24" o.c., 1⅝" x 3 1/16" 18 ga. plate track, diagonal strap bracing, lateral bracing at midpoint and ¾" Type S-12 Low-Profile Pan Head screws.
Stud grade, kiln-dried Spruce-Pine-Fir 2x4 @ 24" o.c., double top plate, 1x4 diagonal let-in windbrace, and 16d nails.	Second Floor Endwalls (Wind load only)	1⅝" x 3⅝" 20 ga. structural cee stud @ 24" o.c., 1⅝" x 3 1/16" 20 ga. plate track, diagonal strap bracing, and ¾" Type S-12 Low-Profile Pan Head screws.
Stud Grade, kiln-dried Spruce-Pine-Fir 2x4 @ 16" o.c., double top plate, 1x4 diagonal windbrace let-in, and 16d nails.	First Floor Sidewalls (Wind, floor and roof loading)	1⅝" x 3⅝" 18 ga. structural cee stud @ 24" o.c., 1⅝" x 3 1/16" 18 ga. plate track, diagonal strap bracing, lateral bracing at midpoint and ¾" Type S-12 Low-Profile Pan Head screws.
Stud grade, kiln-dried Spruce-Pine-Fir 2x4 @ 16" o.c., double top plate, 1x4 diagonal windbrace let-in, and 16d nails.	First Floor Endwalls (Wind load only)	1⅝" x 3⅝" 18 ga. structural cee stud @ 24" o.c., 1⅝" x 3 1/16" 18 ga. plate track, diagonal strap bracing and ¾" Type S-12 Low-Profile Pan Head screws.
Stud Grade, kiln-dried Spruce-Pine-Fir 2x4 @ 16" o.c., double top plate, and 16d nails.	Interior Load-Bearing Walls (Floor load only)	1⅝" x 3⅝" 20 ga. structural cee stud @ 24" o.c., 1⅝" x 3 1/16" 20 ga. plate track, lateral bracing at midpoint and ¾" Type S-12 Low-Profile Pan Head screws.
Utility Grade kiln-dried Spruce-Pine-Fir 2x4 @ 24" o.c., single top plate, and 16d nails.	Interior Non-Load Bearing Walls	1⅜" x 3⅝" 25 ga. standard cee stud @ 24" o.c., 1" x 3 1/16" 25 ga. plate track and ½" Type S Bugle Head screw.
Utility Grade kiln-dried Hem-Fir 2x4	Ladder-back, Fire and Misc. Solid Blocking	1⅝" x 3⅝" 18 ga. structural cee.
½" gypsum board with 1" drywall nail	Drywall, and Attachment to Studs	½" gypsum board with ⅞" Type S Bugle Head screw.

The above data has been provided for comparative purposes only and must not be used for design. Consult manufacturers' data for sheets, values, and specifications.

Table 4g.

The following questions must be answered in order to determine the optimum gage for Wall Studs.

1. What is the desired thickness of the wall cavity?
   —per insulation requirements
   —per mechanical/plumbing requirements
   —etc.

2. What will the standard wall heights be?
   —sidewall studs may be limited by joists/rafters
   —endwall studs may utilize balloon-framing (a 2-story wall)
   —interior wall stud heights are governed by ceiling height, i.e., flat or cathedral ceilings.

3. What stud spacing is preferred?
   —16" o.c.
   —24" o.c.
   —What joist/rafter spacing will be used?

4. Determine wall deflection based on the lateral strength of collateral materials (i.e., exterior and interior sheathing).
   —A brick veneer and impregnated sheathing may limit deflection to L/360.
   —Wood lap-siding on the identical studs may limit deflection to L/240.

5. Determine the wind load that applies to the building location per local codes and specifications

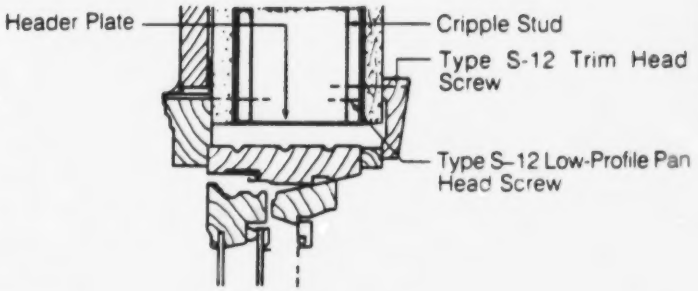
6. Determine the axial loading on the wall.
   —What are the roof loads, both live and dead?
   —What are the floor loads, both live and dead?
   —What are the combined total loads?

From a manufacturer's chart in Part C of Section 4, determine stud gage according to the determined wind and/or axial load conditions. Remember the four basic wall types:
   —exterior sidewall studs; receiving axial and wind loads.
   —exterior endwall studs; receiving wind loads.
   —interior load bearing studs; receiving axial loads.
   —interior partition studs; receiving no load.

The above data has been provided for comparative purposes only and must not be used for design. Consult manufacturers' data for design values and specifications.

Doors and Windows

Wood Window Installation



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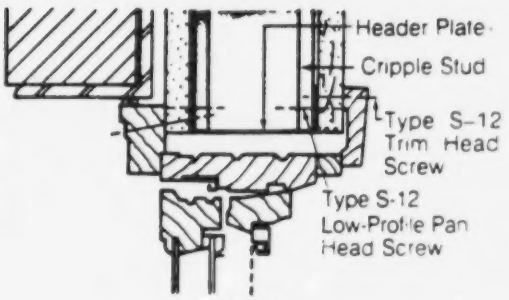

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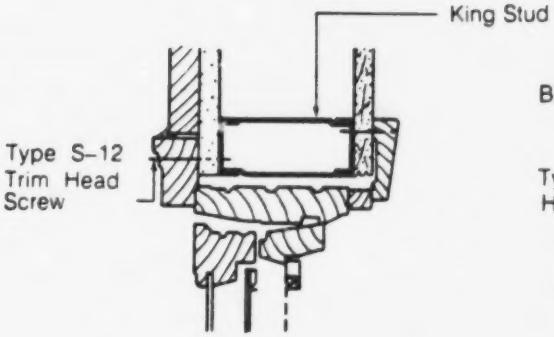

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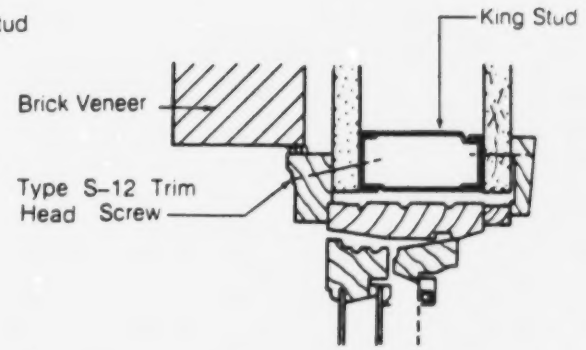

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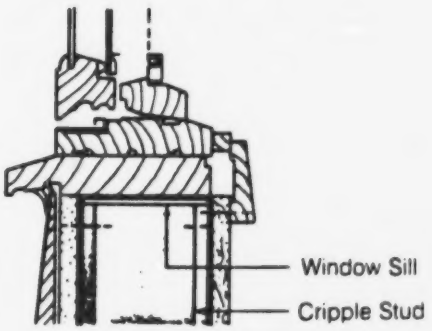

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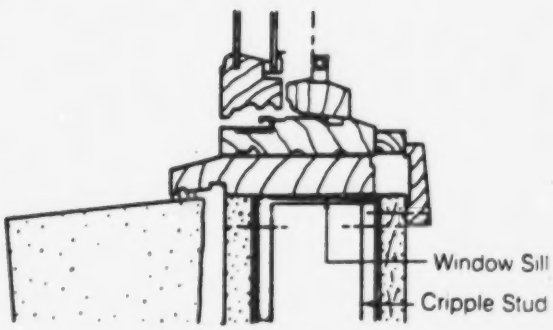
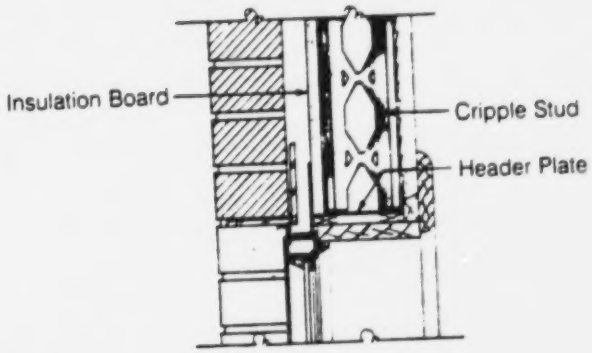


Sill

Illustrations courtesy of United States Gypsum Company

Doors and Windows

Metal Window Installation



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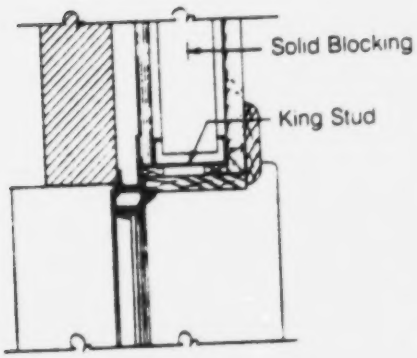

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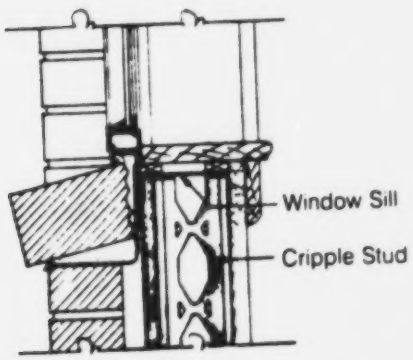
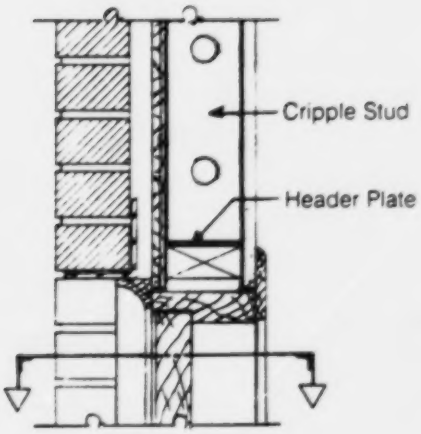


Sill

Illustrations courtesy of Keene Corporation

Doors and Windows

Exterior Wood Frame Door



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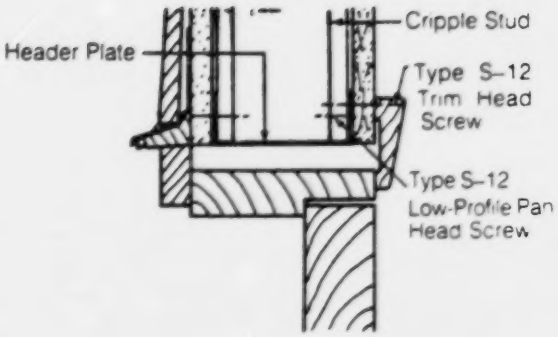

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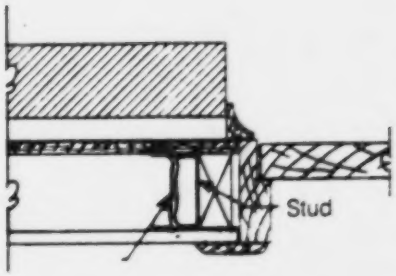

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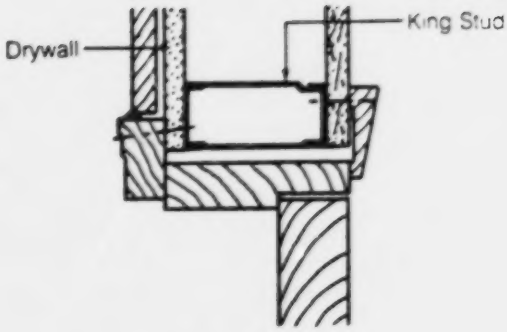

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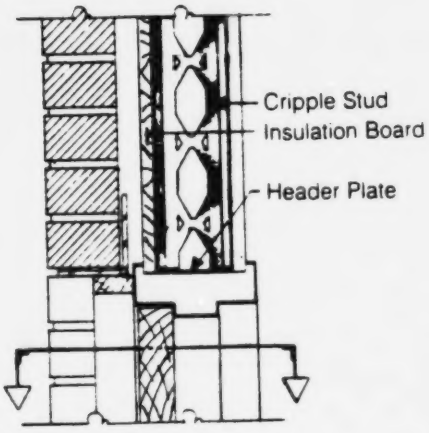
Illustrations courtesy of Keene Corporation
United States Gypsum Company

Doors and Windows

Exterior Steel Frame Door



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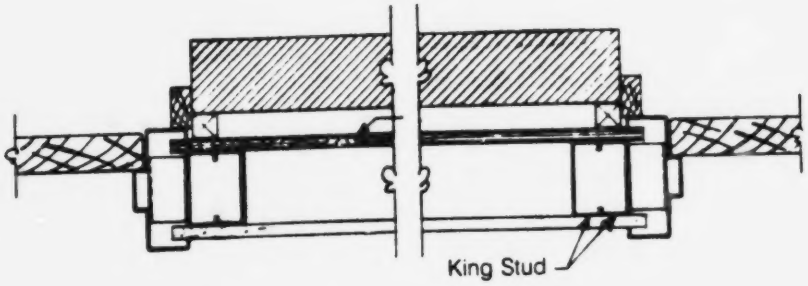

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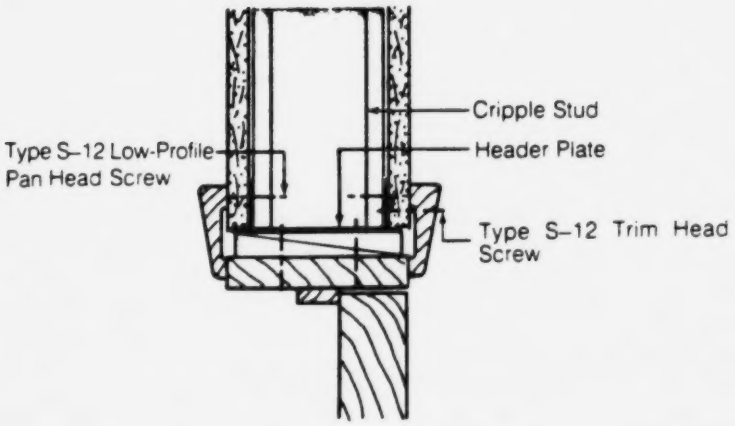
Illustrations courtesy of Keene Corporation

Doors and Windows

Interior Door

Wood Frame



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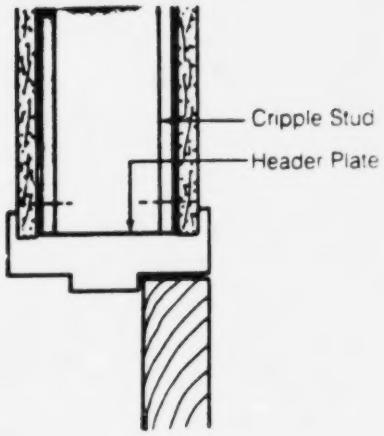
Steel Frame



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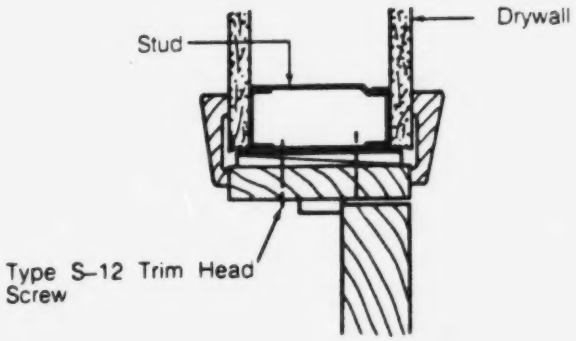

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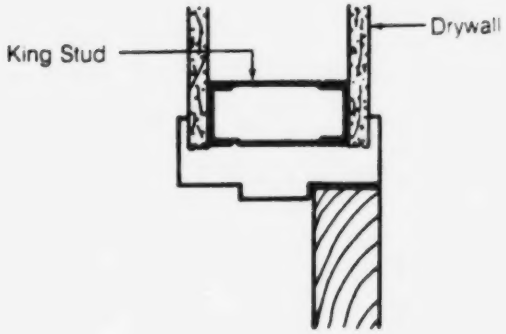

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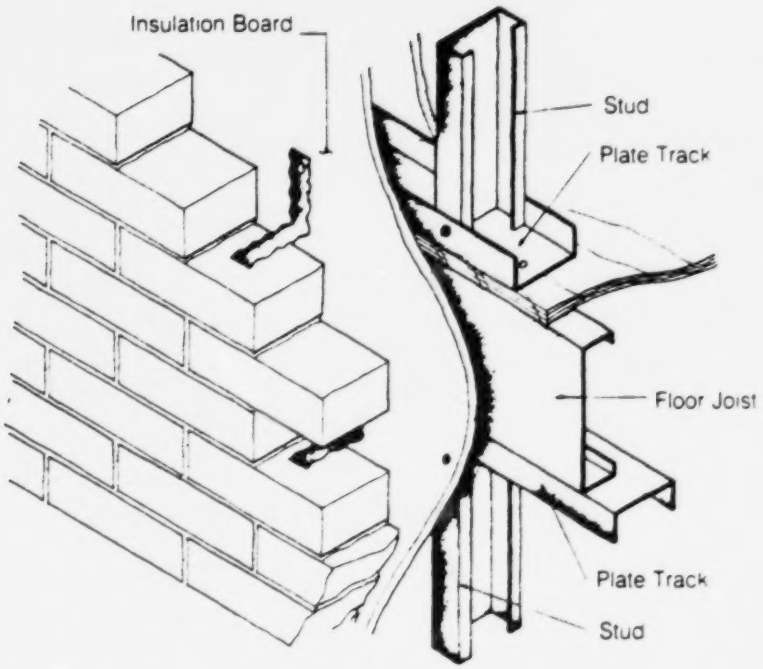
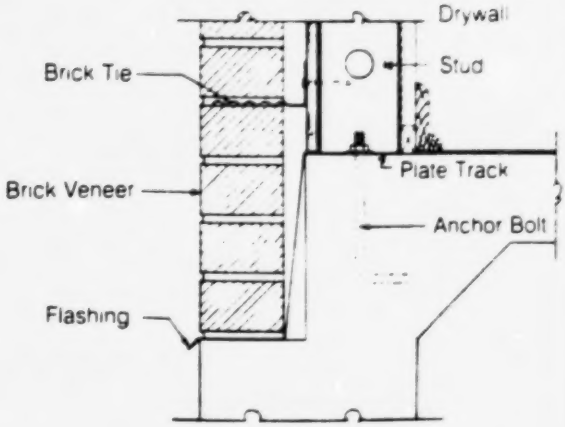
Illustrations courtesy of United States Gypsum Company

Exterior Wall Finish

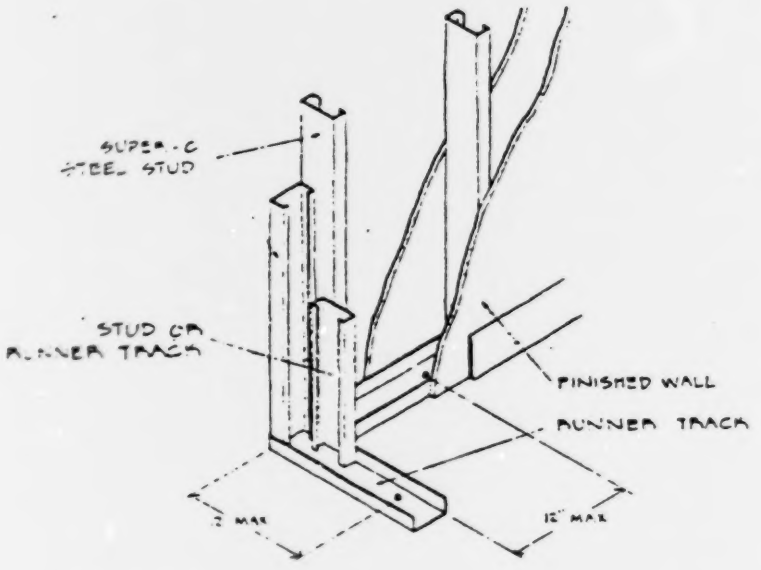
Masonry Veneer





Illustrations courtesy of Keene Corporation
United States Steel

CORNER CONNECTION



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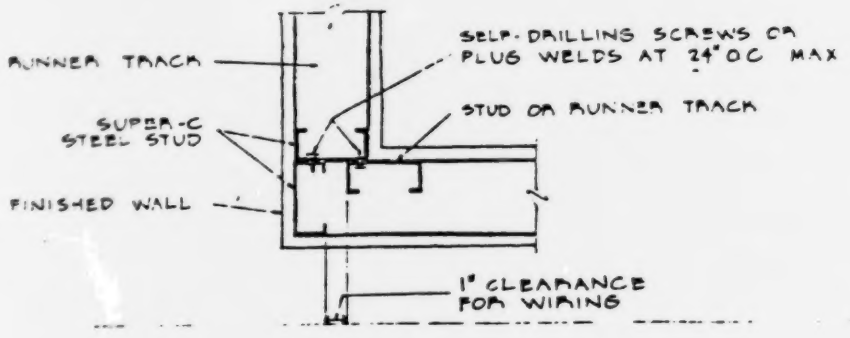

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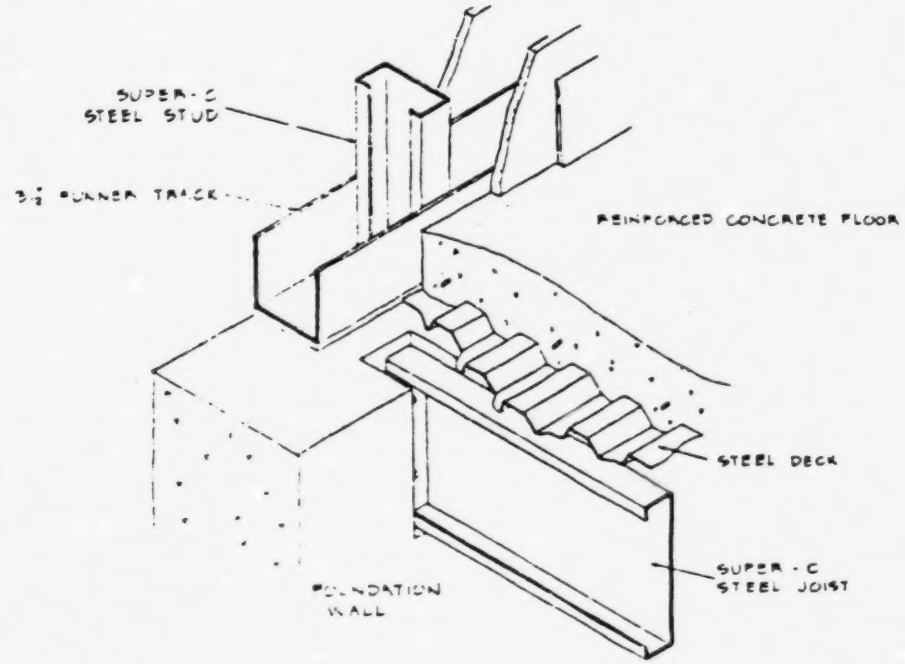
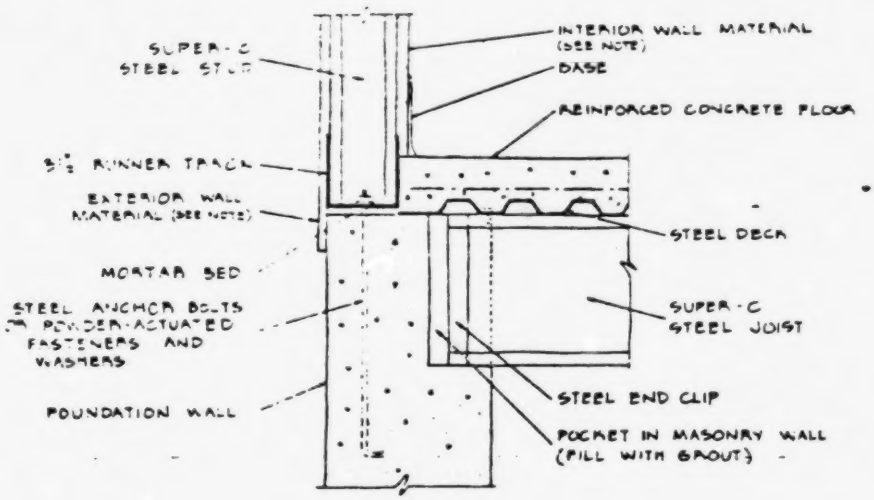
EXTERIOR FRAMED WALL

FIRST FLOOR, STEEL DECK AND CONCRETE



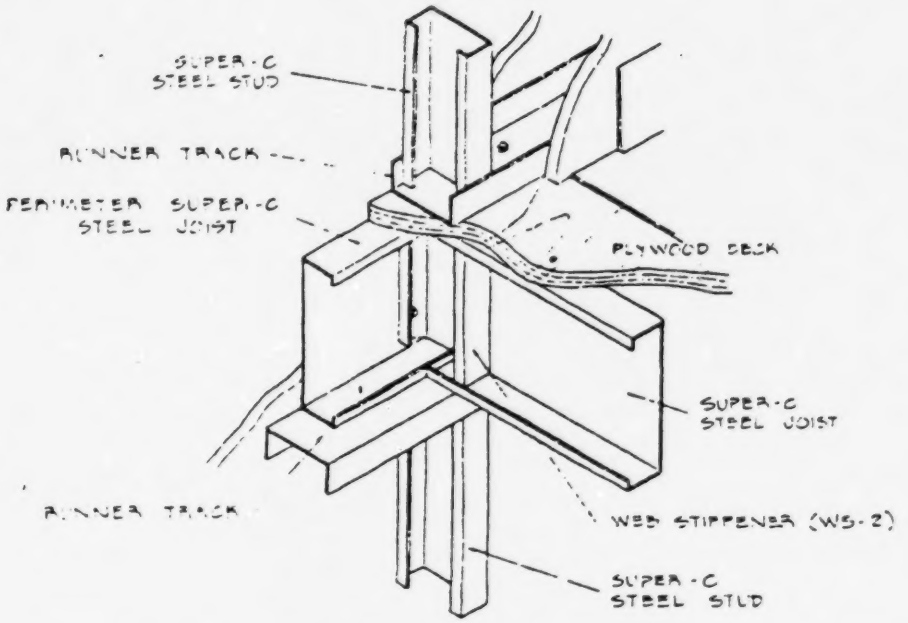


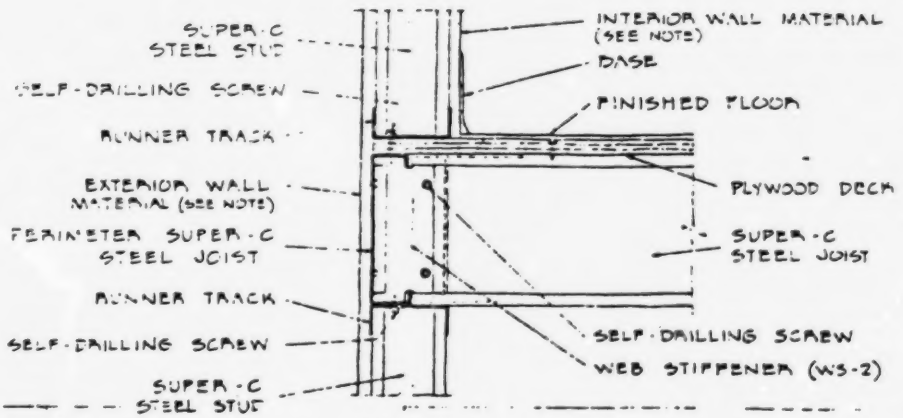
SCALE 1½" = 1'-0"

NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS

EXTERIOR FRAMED WALL

UPPER FLOOR WITH WEB STIFFENER (WS-2), PLYWOOD DECK





SCALE: 1½" = 1'-0"

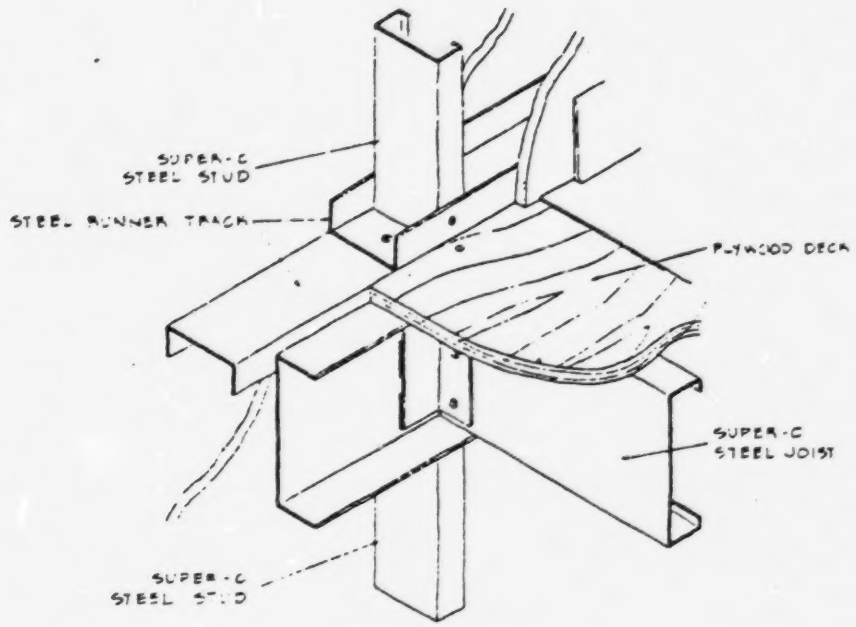
NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS.

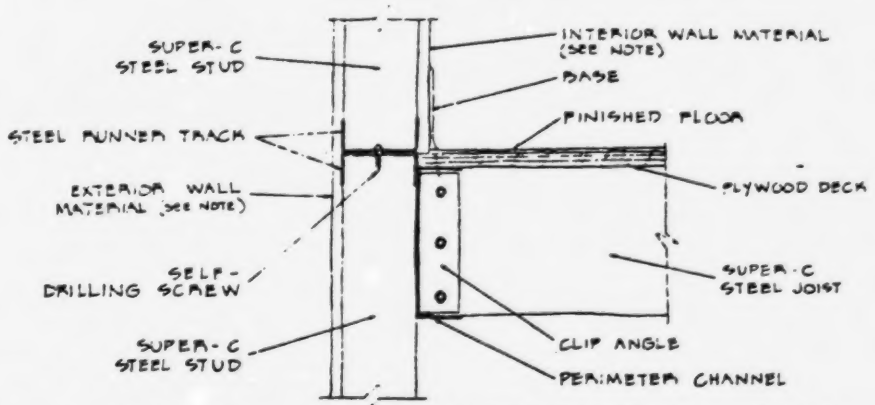
Designed and Developed by USS United States Steel

Super-C Steel Studs

EXTERIOR FRAMED WALL

(STUD ON STUD) UPPER FLOOR, PLYWOOD DECK



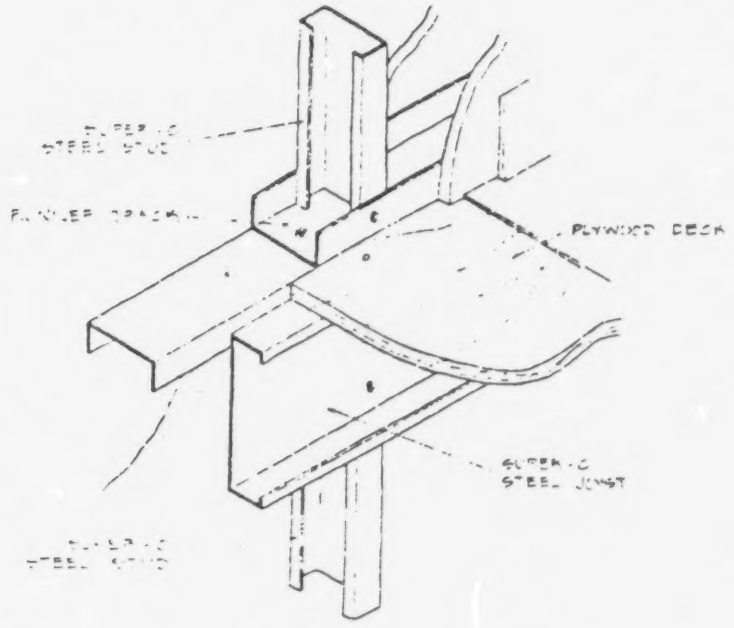


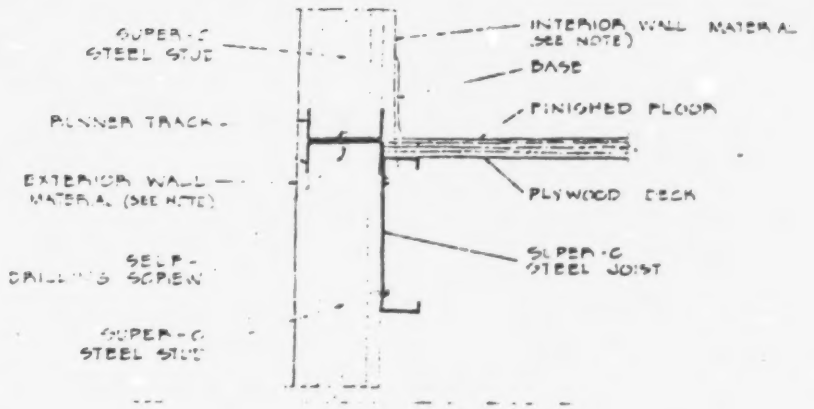
SCALE: 1½" = 1'-0"

NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS

EXTERIOR FRAMED WALL

(STUD ON STUD) UPPER FLOOR, PLYWOOD DECK AND SUPER-C END JOISTS



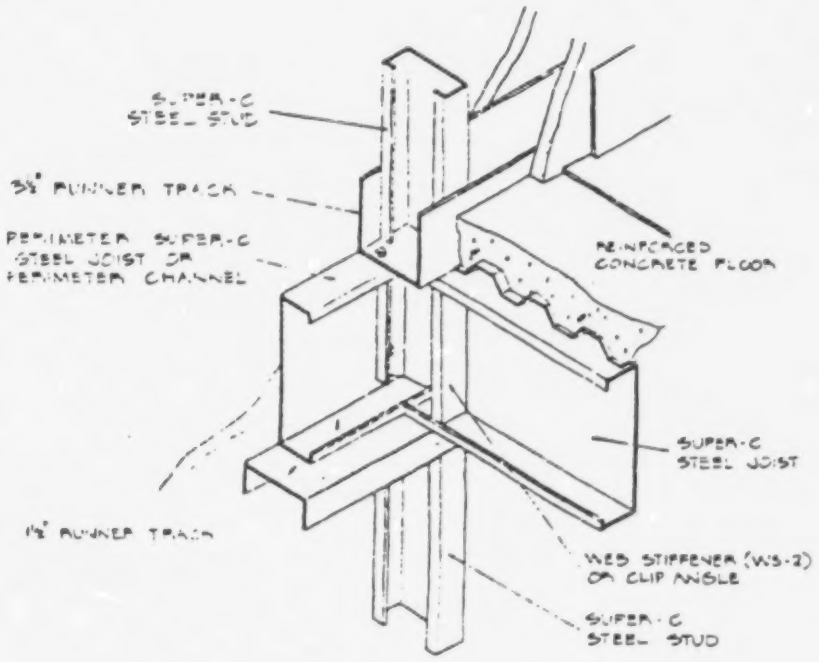


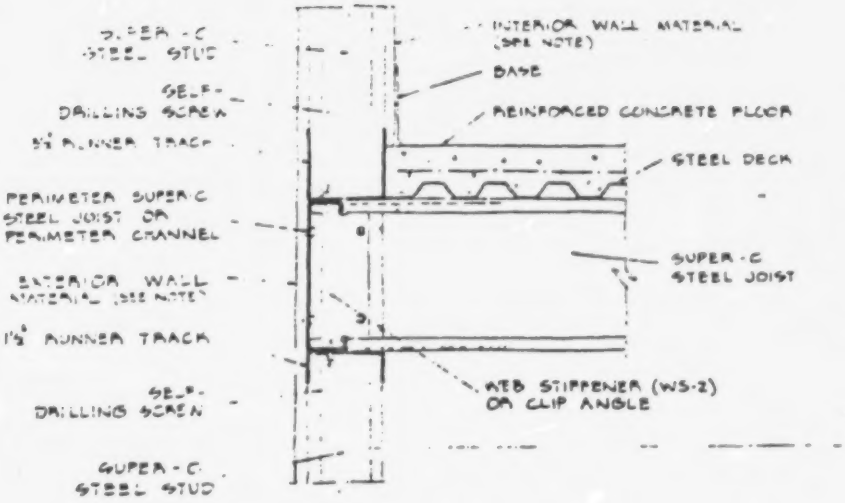
SCALE 1½" = 1'-0"

NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS

EXTERIOR FRAMED WALL

UPPER FLOOR, STEEL DECK AND CONCRETE



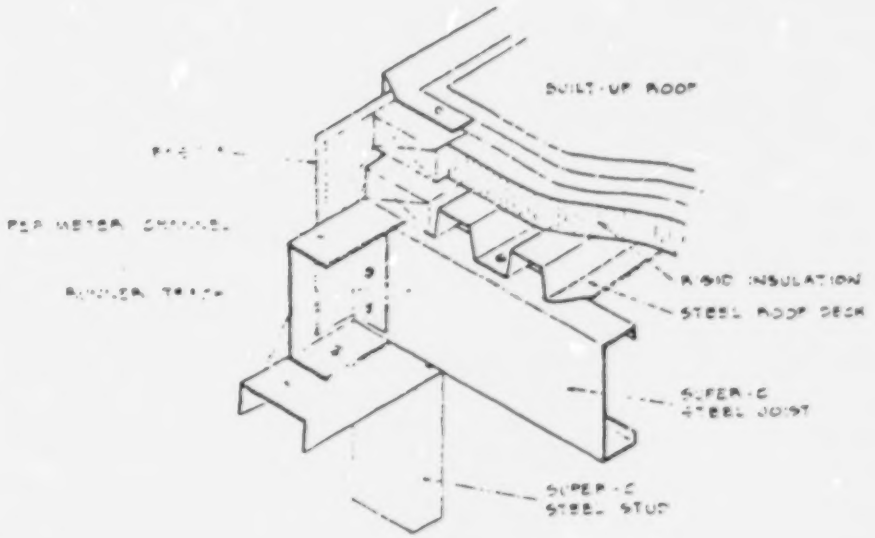


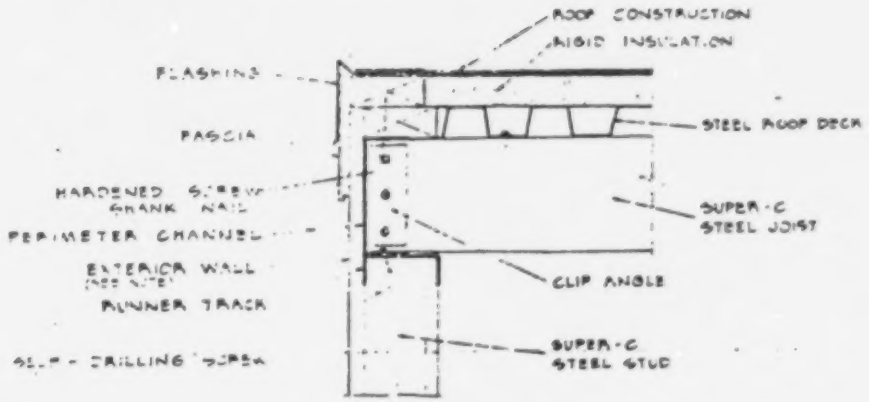
SCALE 1½" - 1'-0"

NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS

EXTERIOR FRAMED WALL

AT ROOF, STEEL JOISTS



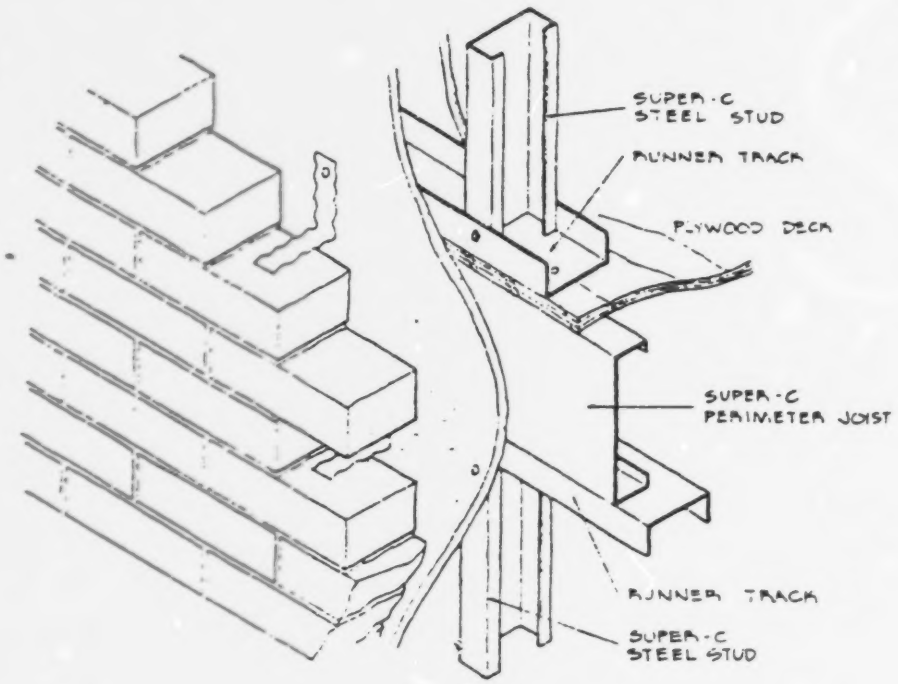


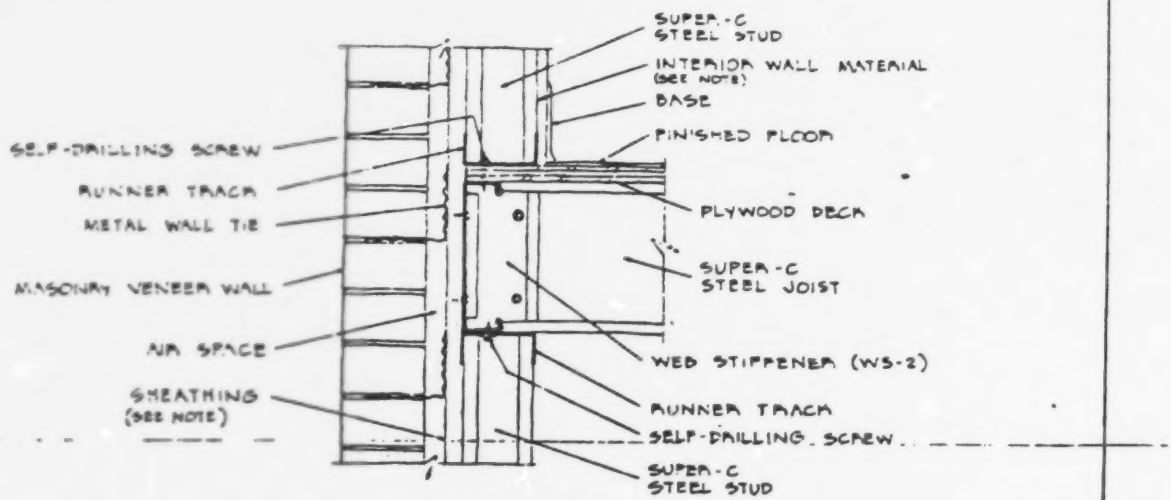
SCALE: 1½" = 1'-0"

NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS.

EXTERIOR FRAMED WALL

MASONRY VENEER



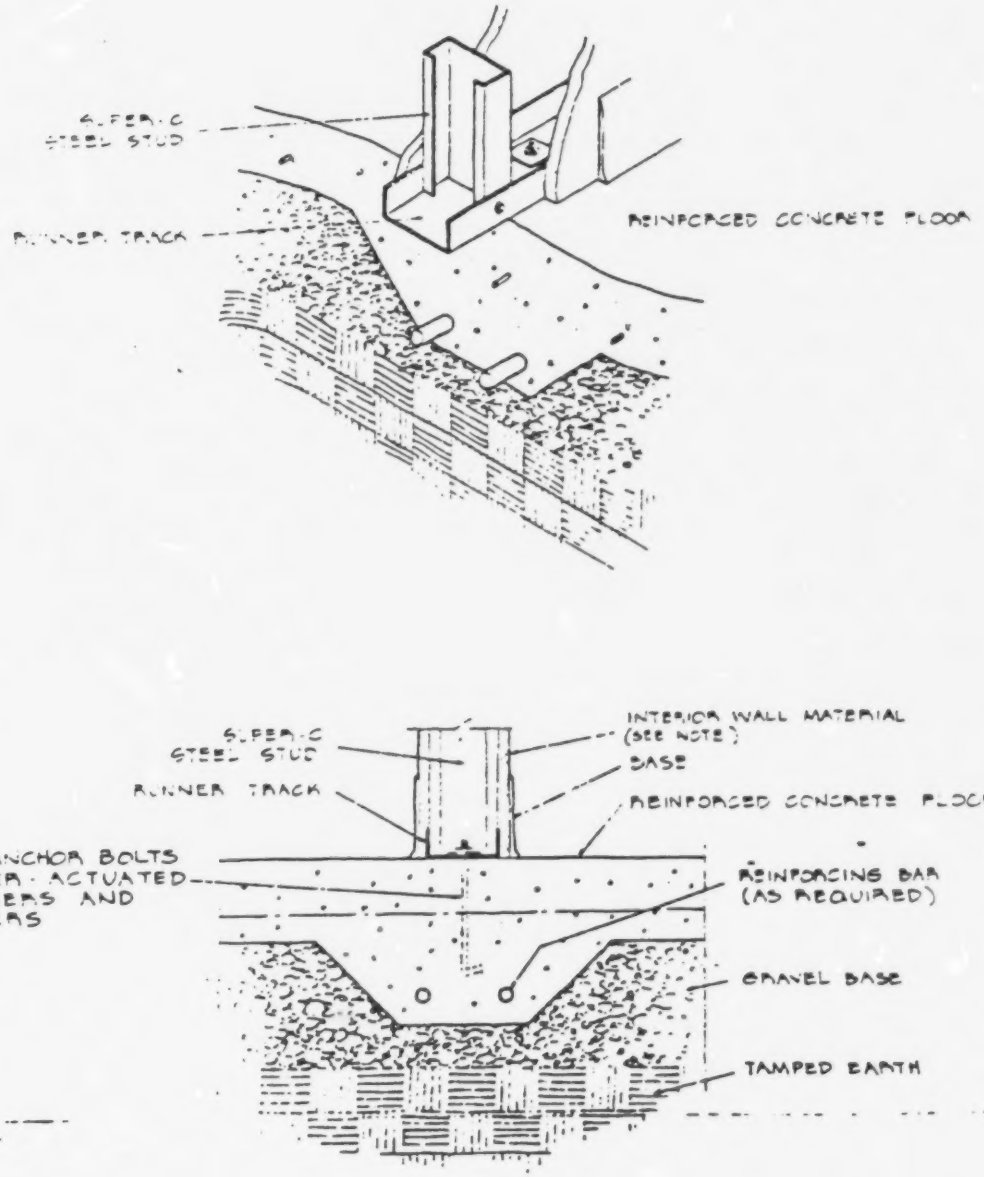


SCALE: 1½" = 1'-0"

NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS.

INTERIOR FRAMED WALL

LOAD BEARING, THICKENED CONCRETE SLAB

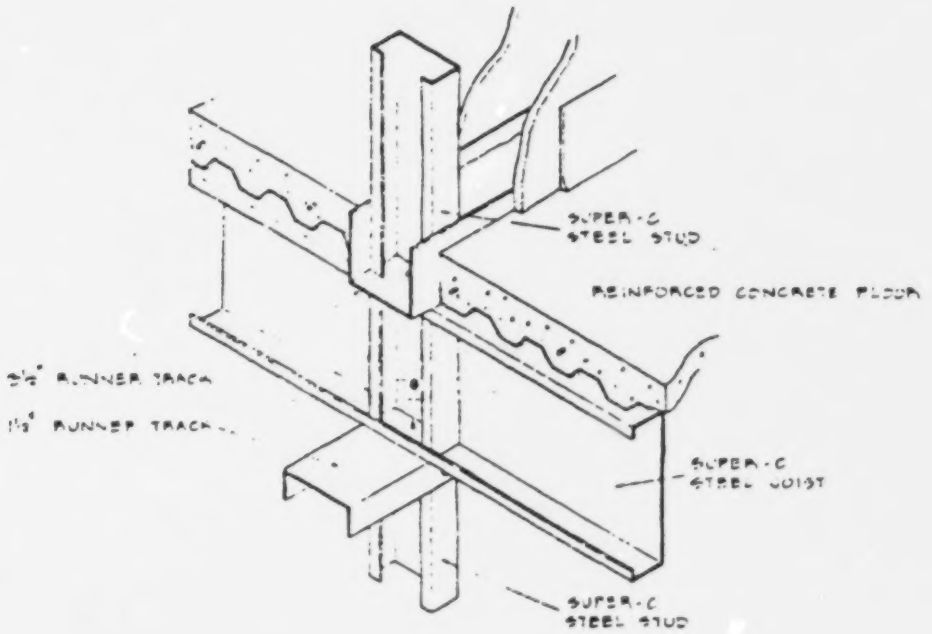


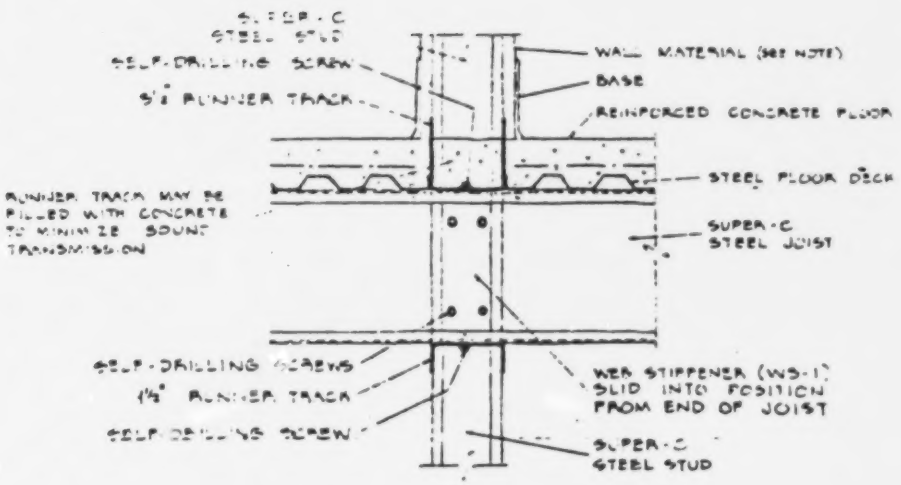
NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS

SCALE: 1½" = 1'-0"

INTERIOR FRAMED WALL

UPPER FLOOR, STEEL DECK AND CONCRETE





SCALE : 1½" = 1'-0"

NOTE:
FASTEN EXTERIOR AND INTERIOR WALL MATERIALS WITH SELF-DRILLING SCREWS OR HARDENED SCREW-SHANK NAILS.

Roof Design

General Design Practices

1. Member Definition:
   a. Refer to "Floor Design" for ceiling member application.
   b. Rafter systems as described have a minimum slope of 3:12.
   c. Rafter not to be spaced more than 48" o.c.
   d. Truss members to be sized and connections specified by qualified engineer only.

2. Minimum Bearing of Rafter at Support:
   a. Steel Rafters are not to be notched to provide seat for bearing.
   b. At exterior wall, provide connection clip or bracket with minimum 2" connecting faces.
   c. At ridge, overlap corresponding rafters unless ridge board is used with rafters opposite each other.
   d. Ridge board to be of nested members, with depth to be the equivalent of the end cut of the rafter.

3. Multiple Rafter Condition Minimums:
   a. Doubled rafters surrounding an opening when dimensions of the opening perpendicular to rafter span exceeds 2 feet.

4. Solid Blocking Conditions:
   a. Within each rafter set where rafters bear across supporting structure.
   b. At ridge unless a continuous ridge board is employed.
   c. Between gable end and first parallel rafter, unless lookouts are used to provide overhang.
   d. Minimum blocking member relative to rafter size as follows:
      —if 4" rafter, use 2½" x ¾", 16 ga. unpunched channel.
      —if 6" rafter, use 3⅝" x ¾", 16 ga. unpunched channel.
      —if 8" rafter, use 4" x ¾", 16 ga. unpunched channel.
      —if 10" rafter, use 6" x ¾", 16 ga. unpunched channel.
      —if 12" rafter, use 6" x ¾", 16 ga. unpunched channel.

5. Bracing Conditions:
   a. Rafters to be connected to adjacent ceiling joists when both members are parallel.
   b. Opposing rafters to be connected by a collar tie when ceiling joists are not parallel to rafters. Collar tie to be within top ⅓ of rafter pattern. Size per qualified engineer's specification.
   c. Interior struts or truss webs are not to be smaller than 1⅜" x 3½" structural cee, with unbraced length of strut not to exceed 8' and a minimum slope of 45° from horizontal.
   d. Stiffback bracing may be used within the span of the ceiling joists in lieu of bridging. See Table 4b. Stiffback bracing may be a single channel or multiple members connected to the top of the ceiling joists.

6. Limitations on Web Holes which are site cut:
   a. refer to "Floor Design, General Design Practices" item 5.

7. As a comparison, refer to Table 4d (simple span values) for allowable spans of roof rafters. The span distances are conservative, as the deflection criteria for floors is L/360, while that for rafters is L/240. Although the rafter spans will be somewhat longer, one can clearly see that many common residential roof spans are easily handled by the smaller member sizes at greater spacing intervals. As individual design situations and respective manufacturer's products will require specific engineering, it is recommended that a qualified engineer analyze both aspects for the optimum member specifications.

The above data has been provided for comparative purposes only and must not be used for design. Consult manufacturers' data for design values and specifications.

Comparative Framing Designs (Wood vs. Light Steel)

1. Design Conditions:
   a. Framed area, spans, supports and bracing
   b. Rafters supporting drywall ceiling
   c. Roof system sloped at 4:12

2. Design Criteria
   a. Live Load: 30 lb/ft²
   b. Dead Load: 15 lb/ft²
   c. Limiting Deflection (live load only): 1/240 clear-span

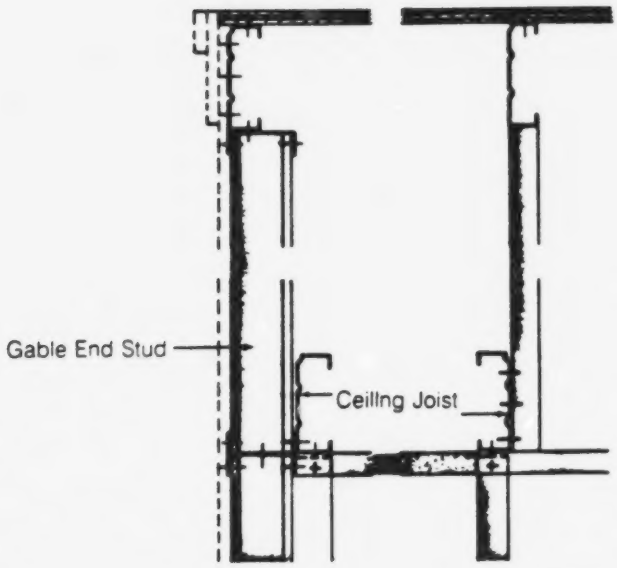
Roof Framing Comparison

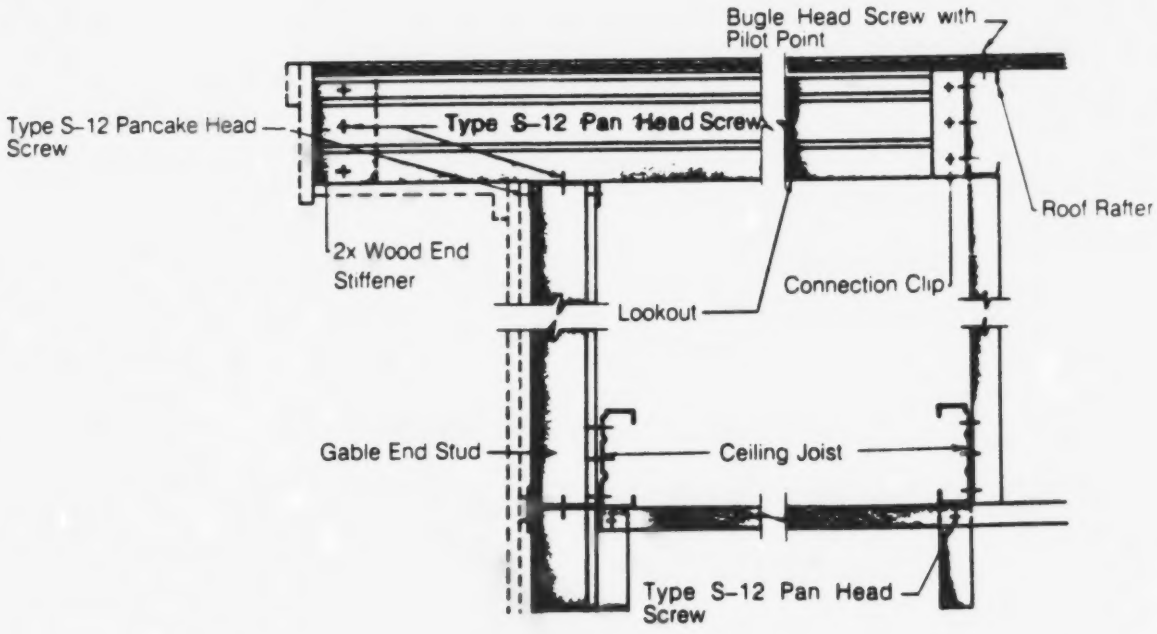
Wood	Framing Item	Light Steel Framing
#2 kiln-dried Spruce-Pine-Fir 2x10 @ 16" o.c., notched to bear on ridge beam, 2x12 ridge board over beam, 16d common wire nails	Rafter Size/Spacing/Span Condition	6", 18 ga. rafter at 24" o.c. full-length, lapped at ridge over beam support, Type S-12 Pan Head screws
Rafter notched to bear on wall, toe-nailed with 8d common wire nails or attached by manufactured hurricane ties	Exterior Wall Attachment	Connection clip with ¾" Type S-12 Pan Head screws
2x10 sub-fascia, 16d common wire nails, 1x12 fascia, 8d common wire nails	Rafter End Closure	6", 18 ga. Rim Track with ¾" Type S-12 Low Profile Pan Head Screws to Web Stiffener and from Web Stiffener to rafter, 1x8 Wood Fascia to Rim Track with 1⅛" screw-shank nails
8d common wire nails, toe-nailed	Rafter to Ridge Beam Attachment	Connection clips, ½" Type S-12 Pan Head screws
½" CDX plywood, 8d common wire nails	Roof Sheathing, and Attachment to Rafters	½" CDX plywood, 1" Type S-12 Bugle Head screw with Pilot Point

The above data has been provided for comparative purposes only and must not be used for design. Consult manufacturers data for design values and specifications.

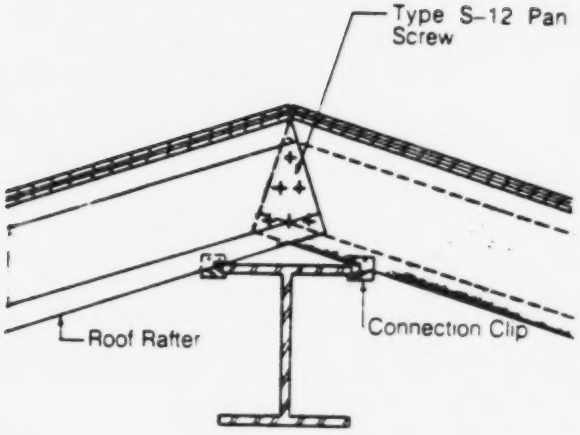
Gable End Framing

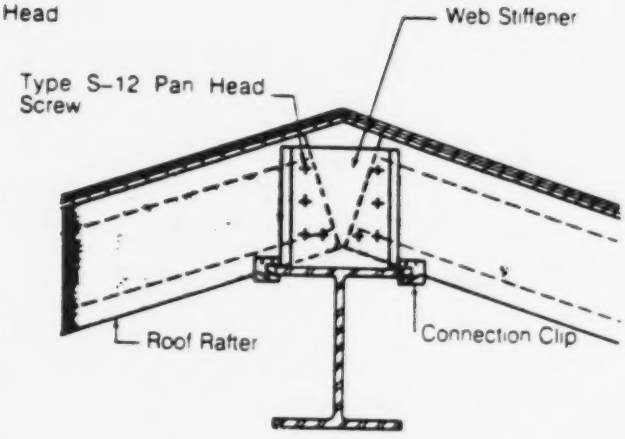
Roof Framing at Gable End

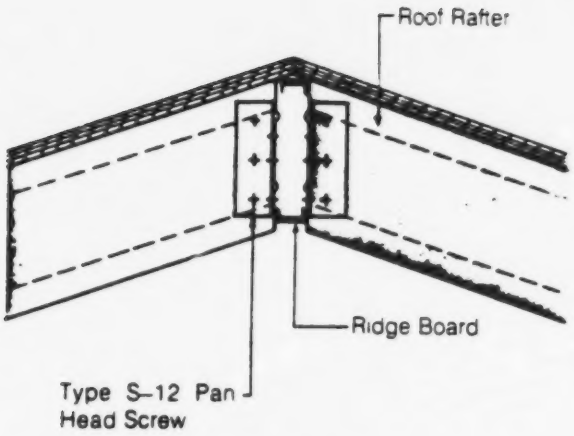


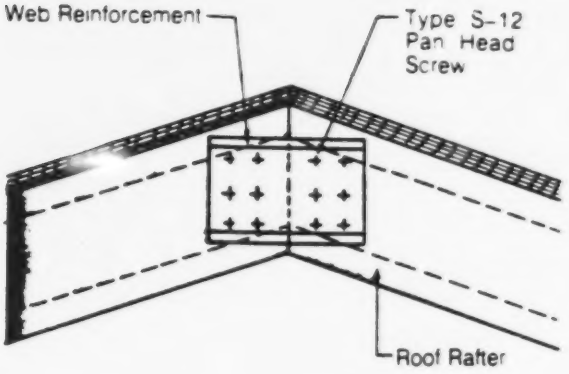


Ridge Connections

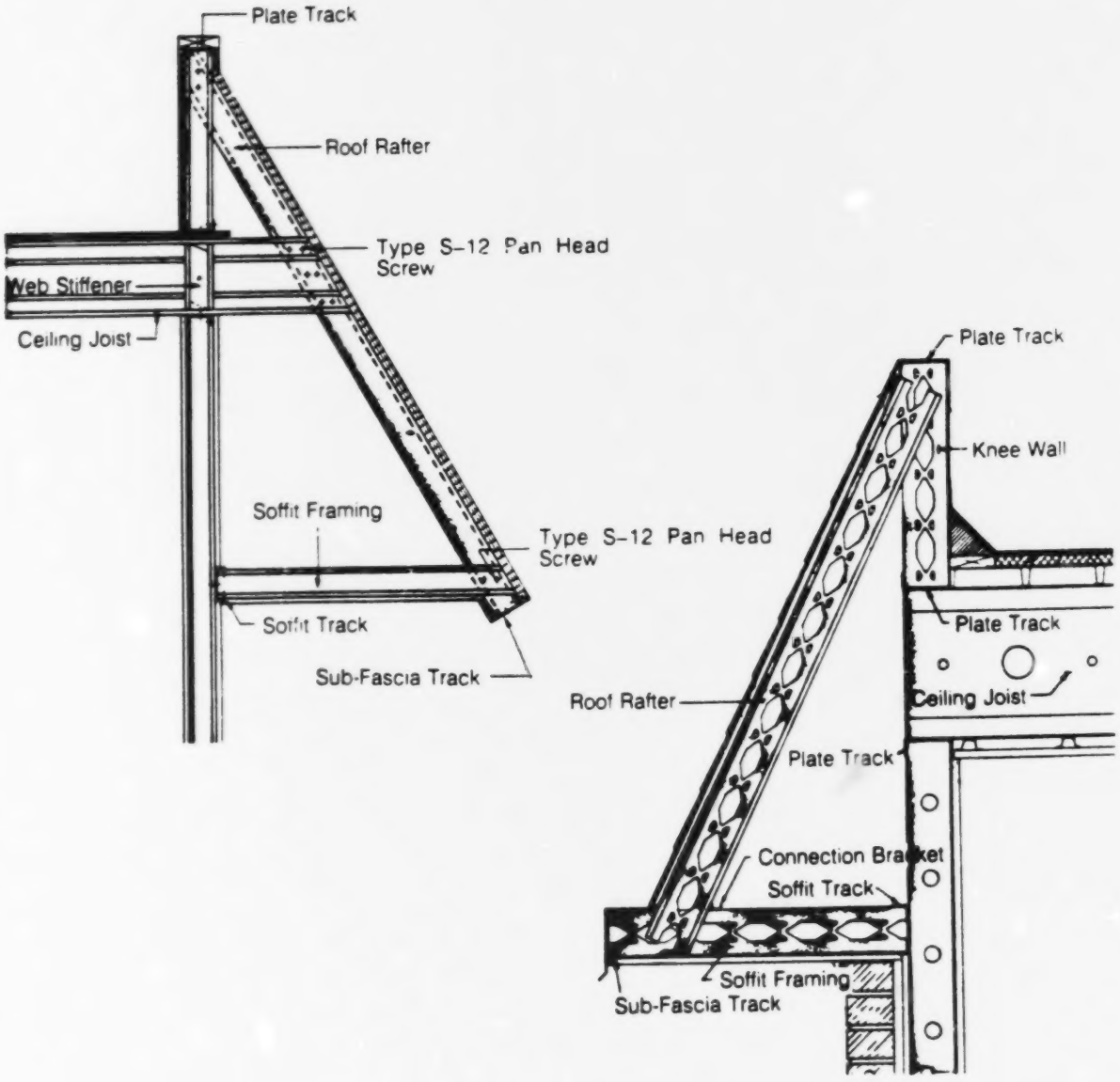


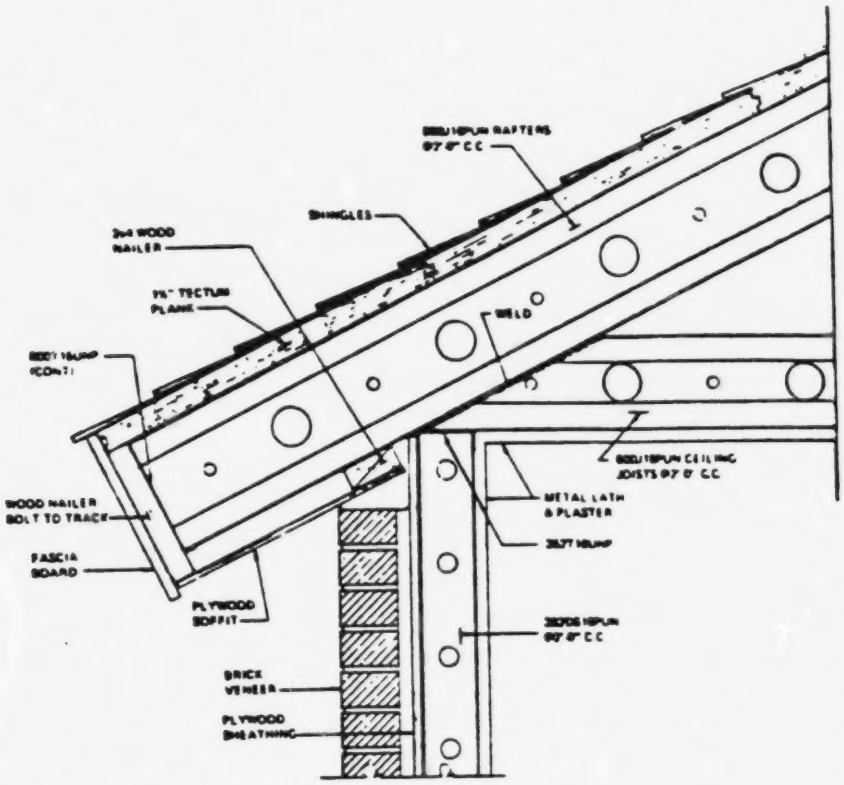


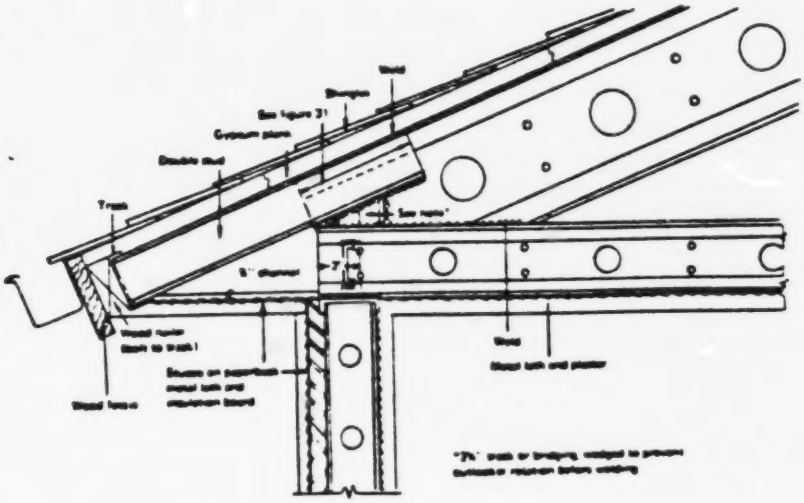




Mansard Roof Details



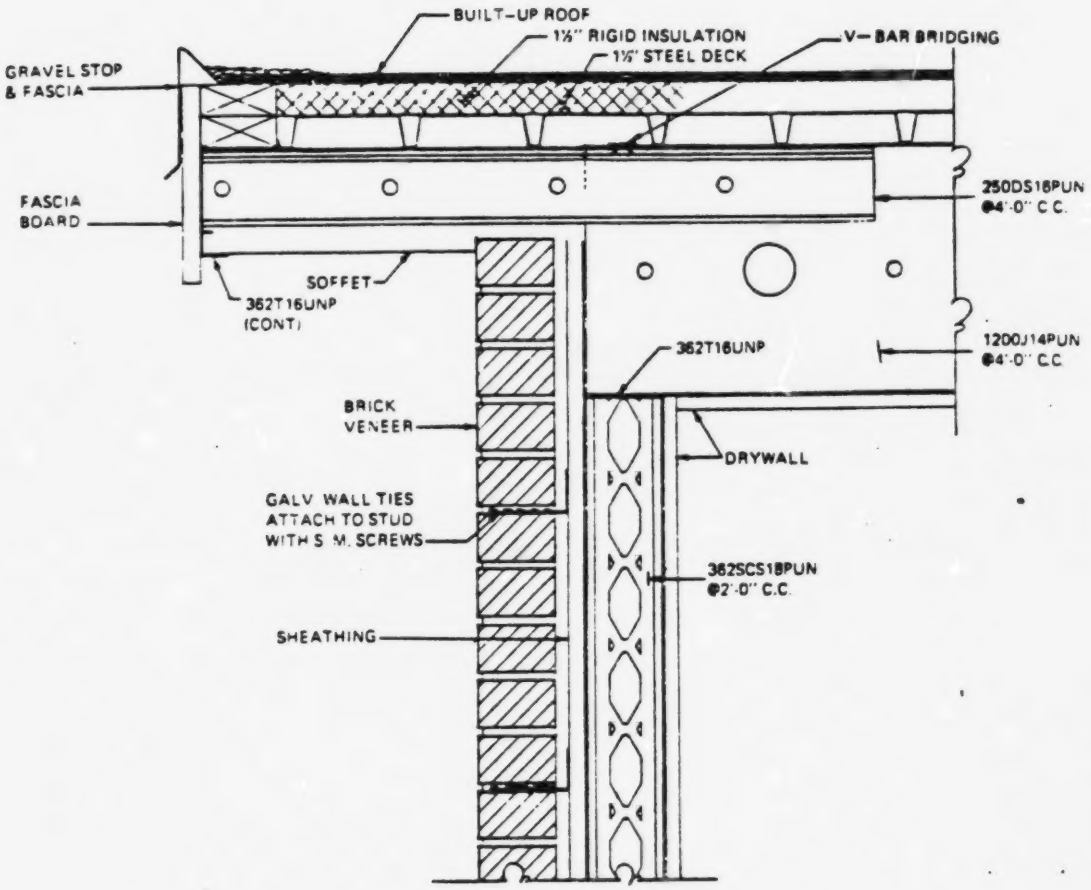




KEENE
CORPORATION

Metal Construction Products Division
Penn Metal Operation
P. O. Box 1408
Parkersburg, West Virginia 26101
Phone 304/295-4581

OVERHANG CLOSURES
DRAWING NO. AS-1-10



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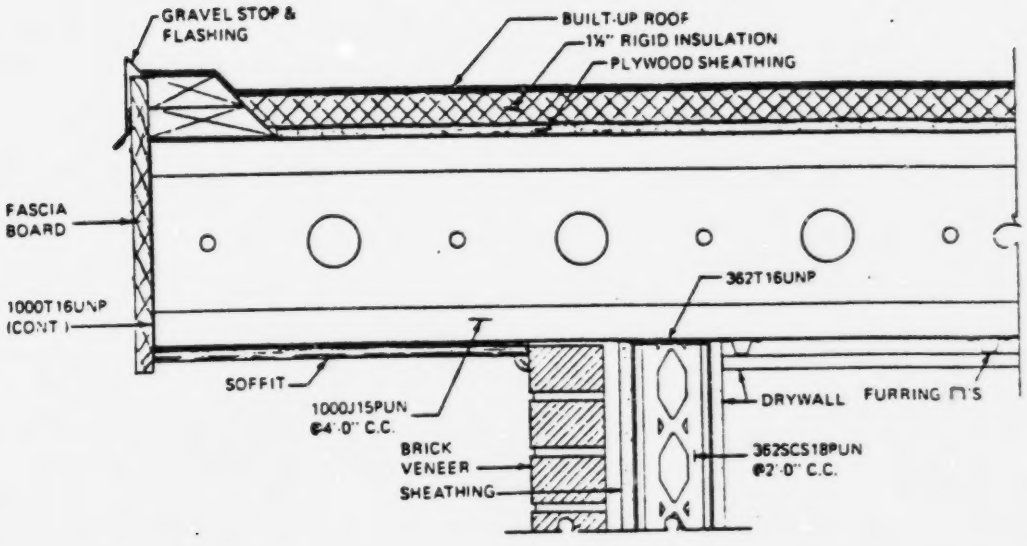
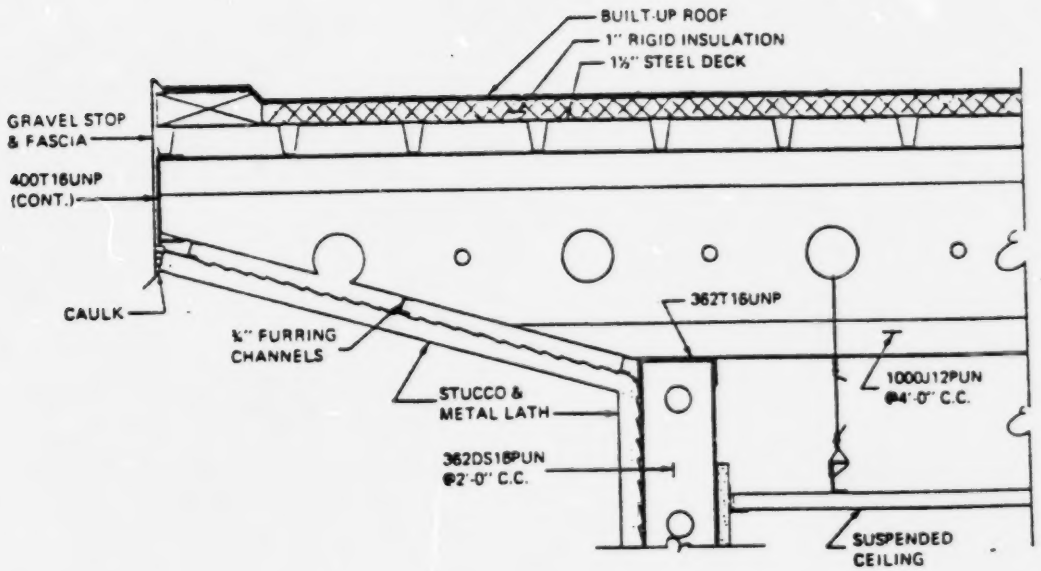
OUTRIGGER DETAIL
DRAWING NO. AS-1-11



FLAT SOFFIT



INCLINED SOFFIT

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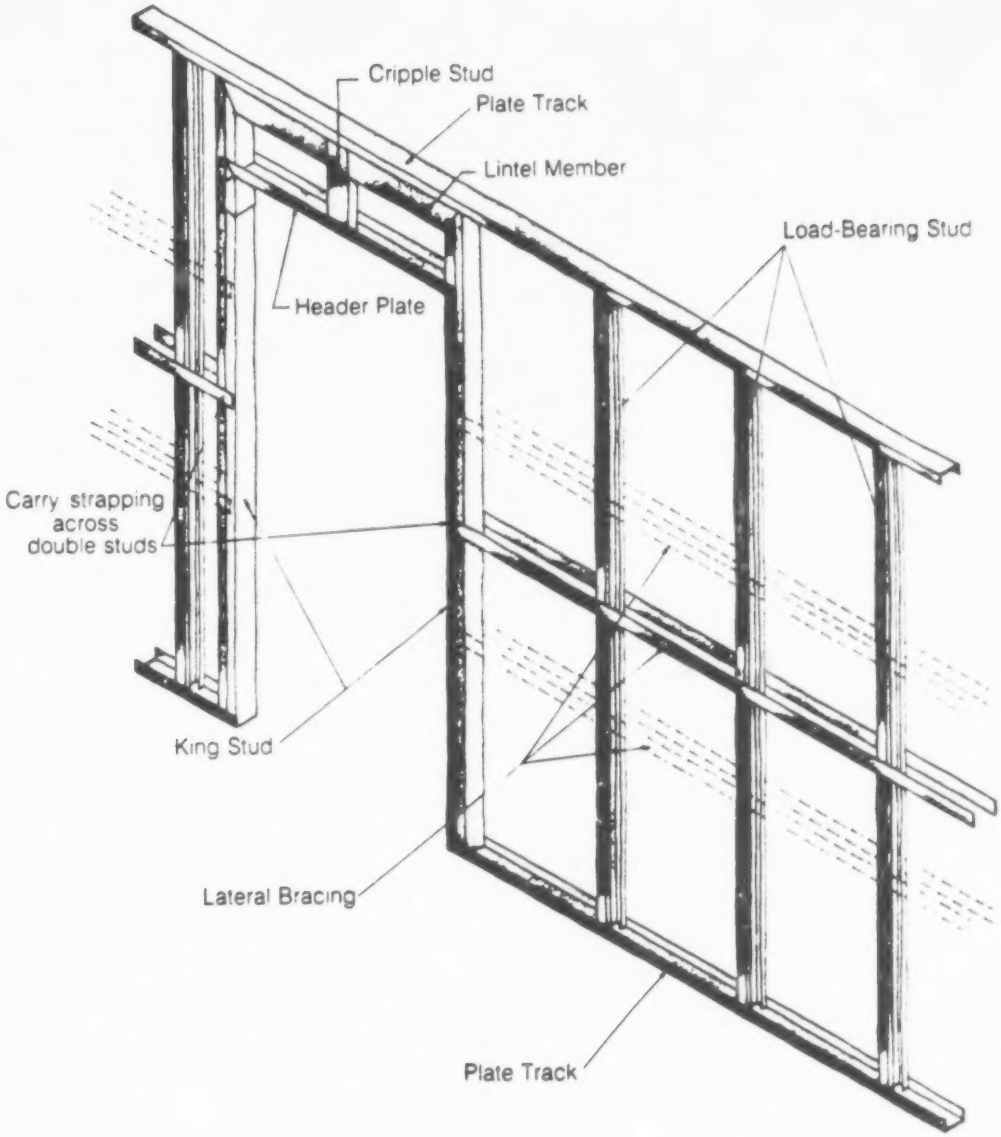
P. O. Box 1468
Parkersburg, West Virginia 26101
Phone 304/295-4561

FLAT OR LOW PROFILE ROOFS
SCALE – 3/4" = 1'-0"
DRAWING NO. AS–4–1

Lateral Bracing

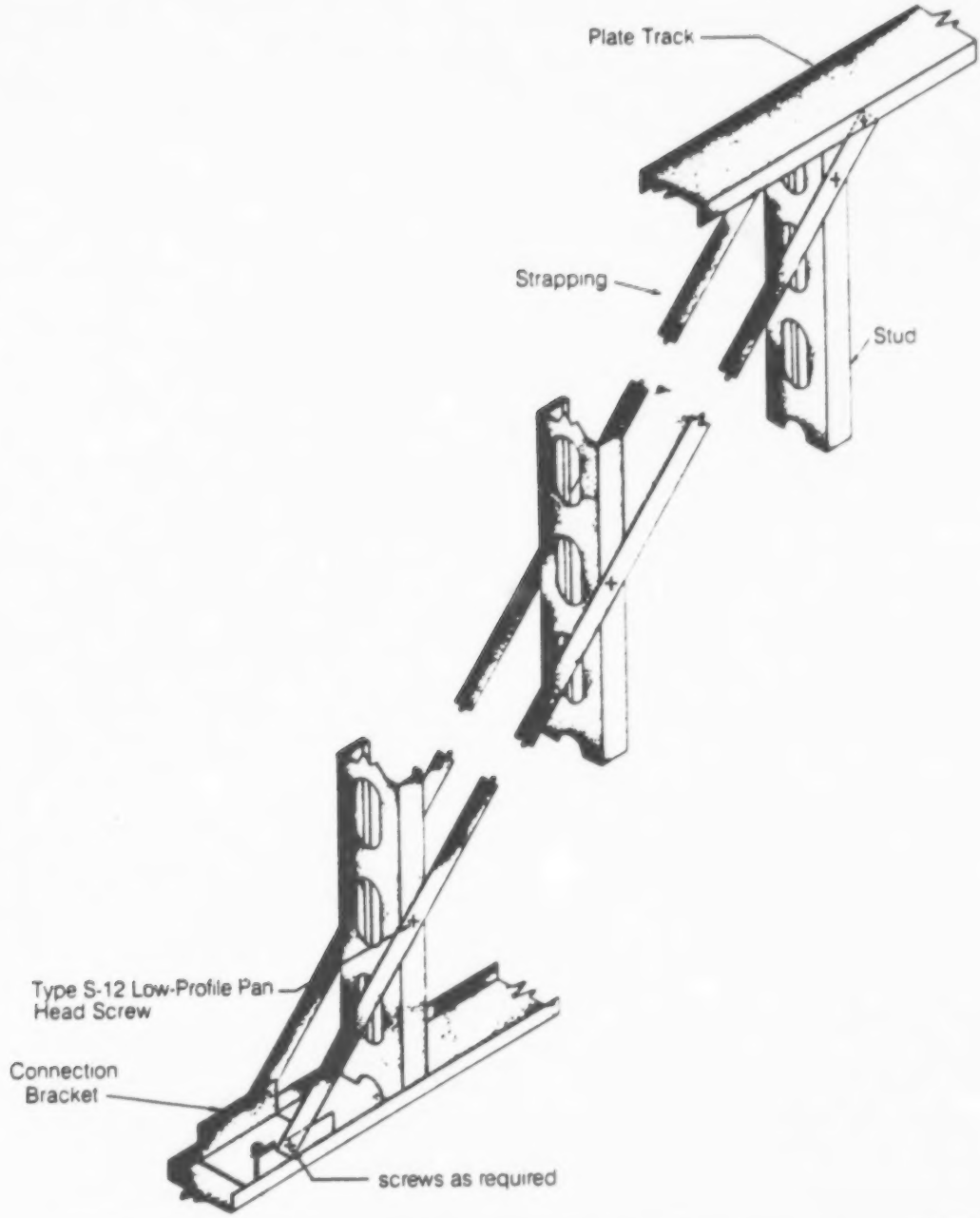
Lateral Bracing; Strapping



Illustrations courtesy of United States Steel

Diagonal Bracing

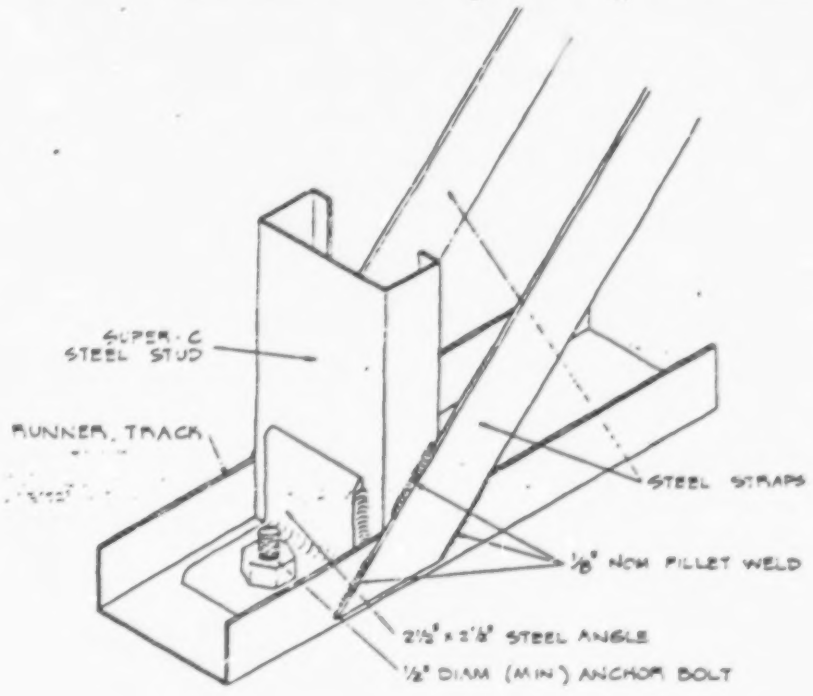
Connection Details

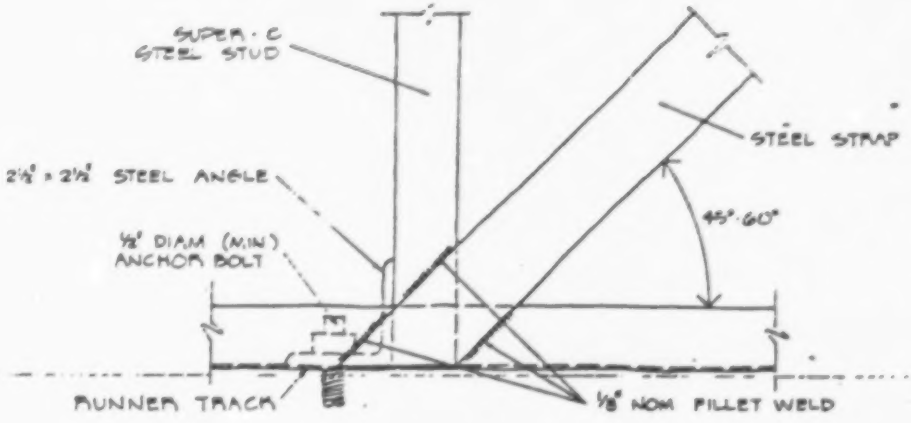


Illustrations courtesy of Wheeling Corrugating Company

DIAGONAL STEEL STRAPPING

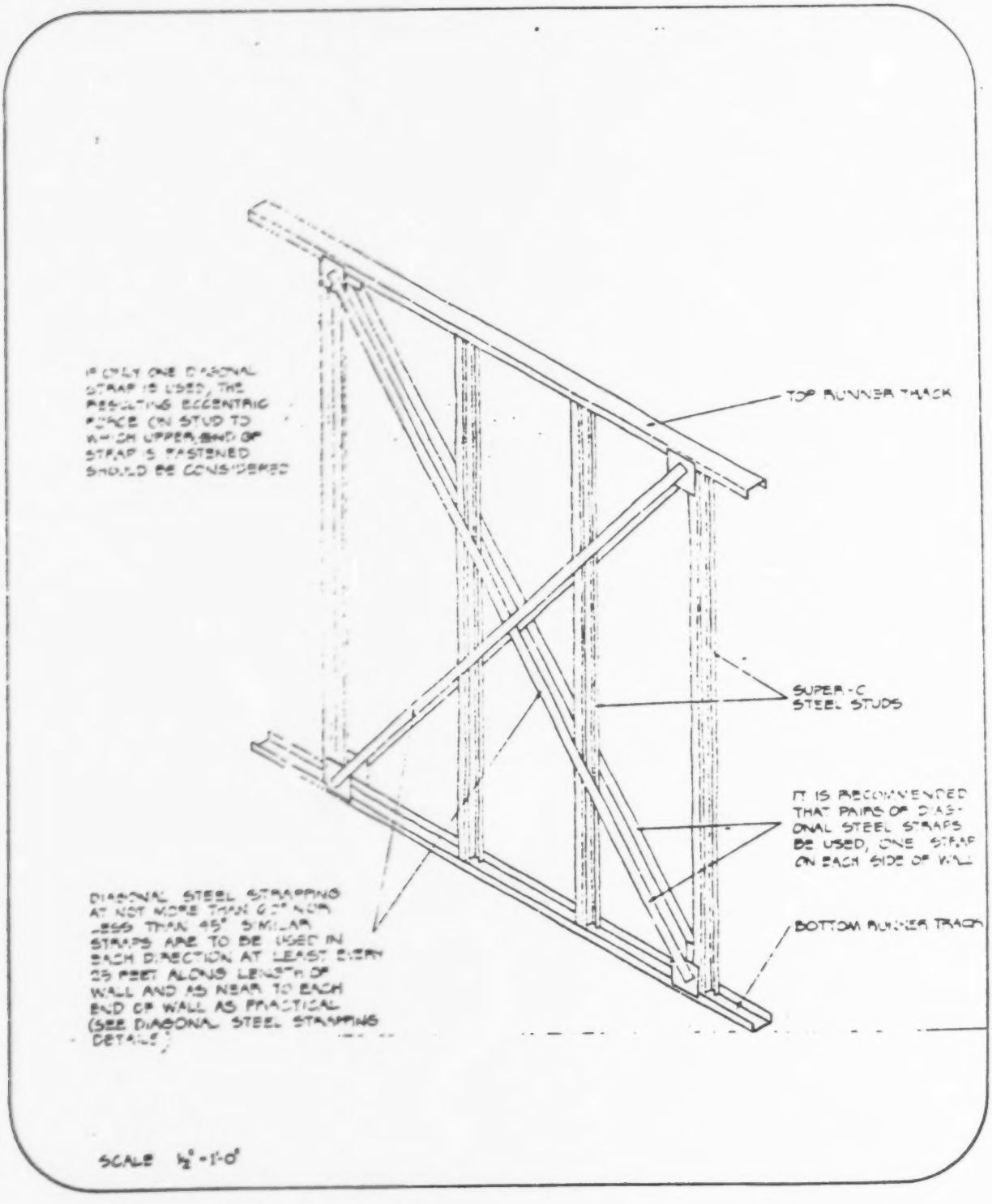
FILLET WELD CONNECTION





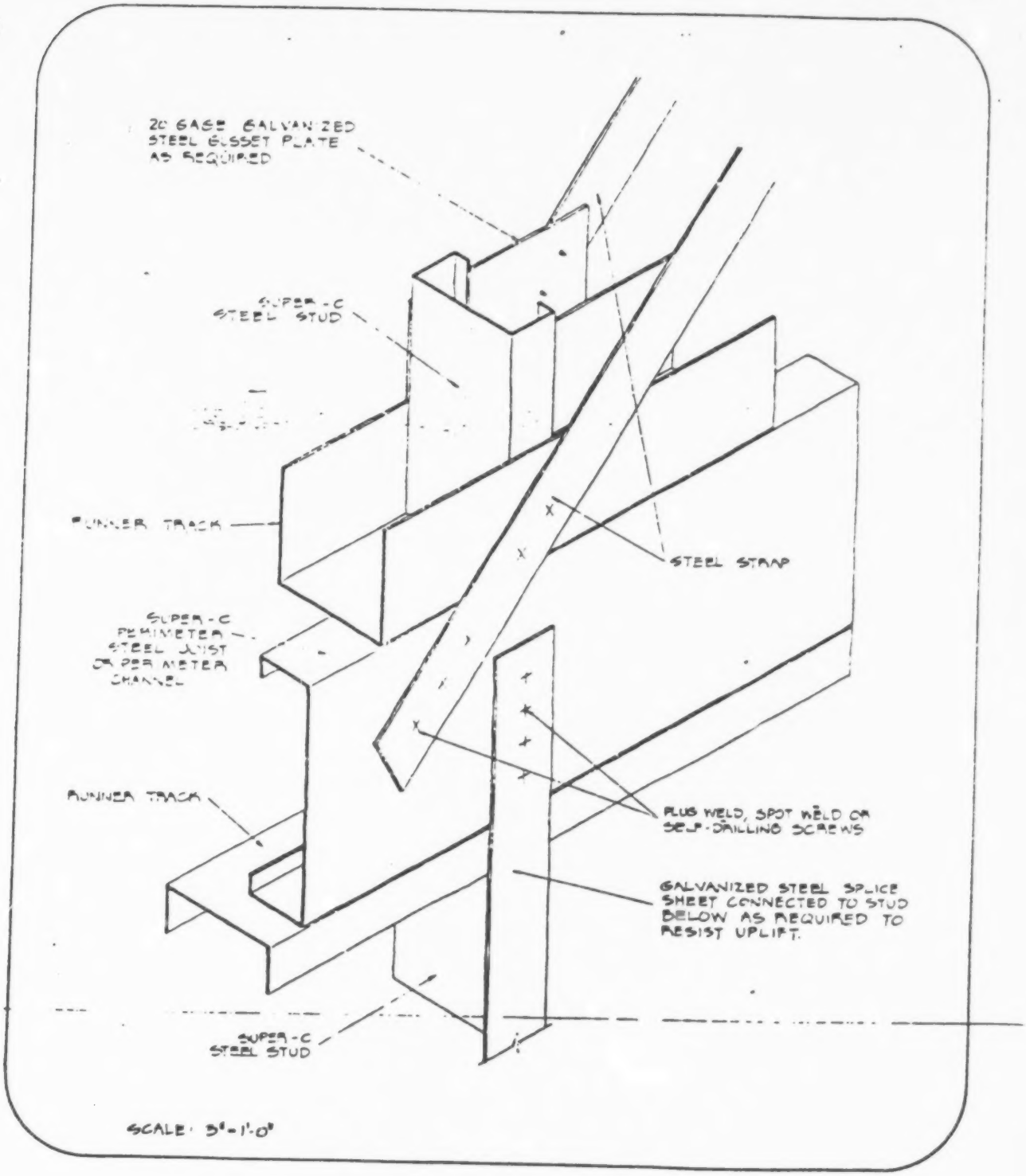
SCALE: 3"-1'-0"

DIAGONAL STEEL STRAPPING


IF ONLY ONE DIAGONAL STRAP IS USED, THE RESULTING ECCENTRIC FORCE ON STUD TO WHICH UPPER END OF STRAP IS FASTENED SHOULD BE CONSIDERED
TOP RUNNER TRACK
SUPER-C STEEL STUDS
IT IS RECOMMENDED THAT PAIRS OF DIAGONAL STEEL STRAPS BE USED, ONE STRAP ON EACH SIDE OF WALL
BOTTOM RUNNER TRACK
DIAGONAL STEEL STRAPPING AT NOT MORE THAN OR NOT LESS THAN 45° SIMILAR STRAPS ARE TO BE USED IN EACH DIRECTION AT LEAST EVERY 25 FEET ALONG LENGTH OF WALL AND AS NEAR TO EACH END OF WALL AS PRACTICAL (SEE DIAGONAL STEEL STRAPPING DETAILS)
SCALE ½"-1'-0"

DIAGONAL STEEL STRAPPING

FLOOR PERIMETER CONNECTION


20 GAGE GALVANIZED STEEL GUSSET PLATE AS REQUIRED
SUPER-C STEEL STUD
RUNNER TRACK
STEEL STRAP
SUPER-C PERIMETER STEEL JOIST OR PERIMETER CHANNEL
RUNNER TRACK
PLUG WELD, SPOT WELD OR SELF-DRILLING SCREWS
GALVANIZED STEEL SPLICE SHEET CONNECTED TO STUD BELOW AS REQUIRED TO RESIST UPLIFT.
SUPER-C STEEL STUD
SCALE: 3"=1'-0"

C. FABRICATION

1. Shop Drawings
2. Handlings & Transportation
3. Shop Layout
4. Construction Equipment

HANDLING AND TRANSPORTATION

Steel framing normally can be handled and transported without expensive equipment. A forklift and flat bed truck will usually suffice.

I. MATERIAL ARRIVAL:

A. Truck unloading.

It is assumed that job requirements call for a full truck load of material. The delivering carrier – whether a common carrier, a steel hauler, or the framing manufacturer – will probably use a flat bed truck or trailer.

The material will be either bundled or palletized. Pallets will generally be approximately 2' wide x 2' high x the length of the material (from 8' long to a maximum of 40'). Weight will generally not exceed 4,000 pounds.

A forklift can handle most unloading jobs quite easily. A spreader-beam with end slings can also be used with a crane, which can be any size from a small cherry-picker to a 50-ton mobile (if one is on the job and advance arrangements for its use are made).

Instead of a crane, some shops may have an overhead bridge crane or monorail available. A sideloader may also be used instead of a forklift.

II. MATERIAL HANDLING:

A. At the job-site.

As the material is unloaded, it can be spotted conveniently around the site.

1. If the structure is single story on a concrete slab, the material can be located approximately where it will be used.
2. If the building is going to be two to four stories high, the material for the upper floors can be stacked around the building where it will be used later, floor by floor.
3. For curtainwall applications, mid- or high-rise, it can be hoisted to its appropriate floor by the boom crane, or taken up the freight or construction elevator. A small dollie or wagon may be required to get the material from the elevator to its usage area.

The material will be either job-site fabricated into panels, or installed a piece at a time. In either event, special equipment is usually not required.

If panelized on a slab or floor, the panels can be tilted into place by hand. If the panels are oversize, or have to be attached to outside supports, a portable crane may be needed. Panels for low-rise buildings can be hoisted into place by a forklift with extendable forks, or lifted by a small boom (cherry-picker).

B. In the Shop.

Material that goes to a shop is either going to be cut to length or fabricated. Assuming the material will be panelized, it can be spotted in the fabrication area while unloading.

1. In either case, the material can be moved from the storage area to the saw by a forklift or an overhead crane.
2. The feed into a saw is generally from a conveyor, roller type stands, or table. The cut lengths continue from the saw on roller stands and can be stockpiled on material wagons. Movement to the wagons will be by hand.
3. Wagons are then moved to the assembly area, consisting of table top jigs, where the cut pieces are fabricated into panels. Again, handling is by hand.
4. Completed panels are moved to a staging area or loaded directly onto trucks. Depending on panel size and weight, either manpower or overhead cranes will be used for loading.

III. TRANSPORTATION:

A. Job-site.

Once material is unloaded at the job-site, further transporting is rarely required.

B. Shop.

Shop-fabricated material must be moved from the shop to the job-site. The distance is generally short; however, it can vary from a few miles to many.

C. Drayage considerations.

In helping to arrive at a decision as to what transporting equipment will be needed, the following seven factors should be carefully considered and evaluated:

1. Panel finish:
   a. If the panel is free of collateral materials (insulation, metal lath and plaster, etc.), it can be easily transported flat. If not, vertical shipment is usually called for.

Unfinished (frame only) panels are obviously not as delicate as those with a finish on one side. They can be readily handled and transported without extra precautions, and more panels can be loaded and moved at one time.

A semi-finished panel will require more care in loading, blocking, tying down, unloading, and erecting. Difficult site conditions may justify the extra expenditure for this type of panel.

2. Transporting distance:
   a. Short haul (0-50 miles)
      The ideal distance. Few problems should be encountered.
   b. Medium haul (50-100 miles)
      Can be practical if the project is large and existing shop space is available.
   c. Long haul (100 + miles)
      Usually not practical, particularly if the loads are over-sized (see 3 & 4 below), or the job-to-shop route is through a congested urban area. A long haul through a rural or suburban area, on the other hand, may be justifiable.
3. Panel size:
   a. 8' high x X' long (single story or in-fill curtainwall, floor to beam, column to column).
   b. 8' wide x X' high (3 story curtainwall by-pass).
   c. 8' wide (standard truck bed).
   d. Oversize panels – may require over-the-road permits.
4. Permits (check local and state regulations):
   a. Overwidth
      Up to 8' no problem
      8' to 10' permit only ($15 to $50, depending on state).
      10' to 12' permit plus lead car.
      12' to 14' permit plus lead and tail car
      (Freight rate approx. 200% of normal).
   b. Overlength
      Up to 4' permissible with red flag.
      Over 4' permit plus additional tail lights
   c. Overheight
      Up to 13' or 14' (from ground) permissible depending on state.
      Over 13' or 14' requires permit and careful route selection to avoid most underpasses.

d. Restrictions
All permits are limited from dawn to dusk, no weekends, no holidays.

5. Weight of the panels:
   a. Not usually prohibitive since a steel framed panel (unfinished) will weigh only around 2 pounds per sq. ft.
   b. Volumetric space is usually filled before weight limitations are reached.
6. Number of trips:
   If a large number of trips or oversized loads are required through a congested area, the freight expense may be prohibitive and job-site fabrication should be considered.
7. Job-site conditions:
   a. Ample space – panels could be delivered and stock piled in advance of erection.
   b. Restricted space – panels may have to be erected off the truck as they are delivered.

D. Vehicle selection:

Once an evaluation has been made to satisfy the considerations covered in C above, and depending on available equipment, the actual vehicle will fall into one of the following categories:

1. Flat bed trailer (with a pick-up truck).
2. Regular flat bed truck (16' to 20' bed).
3. Tractor and semi-trailer (flat bed – 36' to 50').
4. Lowboy tractor-trailer.

Item 1 above is recommended for small panels, a short haul distance and a relatively small job. Item 2 should be considered for a medium haul distance, average size panels and a small or medium sized project.

For a large project requiring several loads on a medium or long haul, with possible oversized panels, a tractor-trailer rig would be ideal.

A lowboy tractor-trailer is generally recommended for semi-finished panels, oversized panels, or oversized panels that are going to be transported vertically.

IV. SUMMARY:

The first determination the contractor has to make is whether to fabricate on-site or in his shop. Factors influencing this decision will depend on:

A. Size of the project:
   1. Actual physical size
      a. Single story
      b. Low-rise
      c. High-rise
   2. Amount of light-gage steel framing required.

B. Available Facilities:
   1. Adequate shop
   2. Available equipment

Ingenious workmen have developed some very innovative methods of handling and transporting light gage steel framing. These methods are usually adopted to suit job conditions or to utilize equipment they have at their disposal. Contractors should be alert for such possibilities and encourage their development by both foreman and craftsman. Saving time and movement will pay big dividends.

SHOP LAYOUT AND FIXTURES

The fabrication of light gage steel framing wall and floor panels consists of cutting the members to length, fitting the sections together, and fastening the sections by welding or screw attachment. Often fabricators may go one step further and attach the exterior sheathing or insulation board onto the panel.

Fabrication of the panels at a fabricating shop often offers many advantages over site fabrication. Some of these are:

A. Site conditions may be such that room for the fabrication of panels and storing of materials is not available. Some jobs require the panels to be erected right from the panel transporting truck.
B. Shop fabrication of panels can commence while site work and footings are being poured. Therefore, the panels can be ready for erection as soon as the foundation or slabs are ready to receive the panels.
C. Shop fabrication can continue through bad weather.
D. Fabrication costs often are lower. Workers are more proficient in a shop environment, where an assembly-line type system can be readily established.
E. Quality of workmanship is often better. Shop welding in a controlled atmosphere is superior to field welding, especially with the Gas Metal Arc Welding (GMAW) process.

To fabricate light gage structural framing systems economically and successfully, a fabricator should have an adequately equipped shop.

Figure 1 shows a typical shop layout with equipment and supplies conveniently located and planned for efficient movement of materials. Here are some general and basic recommendations:

A. Establish proper in-process flow. When planning your assembly and fabrication shop, materials must move smoothly and rapidly from one station to the next.
B. Avoid delays or bottlenecks in the flow of product by placing tools, framing materials, and supplies close to the work tables and within easy reach of workers.
C. Timing is important in that assembly and fabrication proceed with the needs of the job. For example, balance the fabrication to meet the speed of erection.

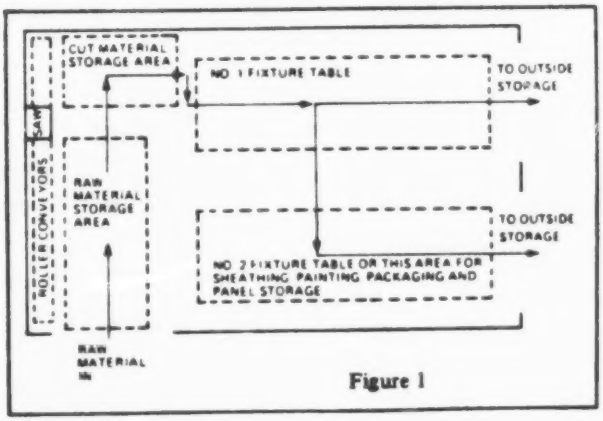

CUT MATERIAL STORAGE AREA
NO 1 FIXTURE TABLE
TO OUTSIDE STORAGE
SAW
ROLLER CONVEYORS
RAW MATERIAL STORAGE AREA
TO OUTSIDE STORAGE
NO 2 FIXTURE TABLE OR THIS AREA FOR SHEATHING PAINTING PACKAGING AND PANEL STORAGE
RAW MATERIAL IN

Figure 1

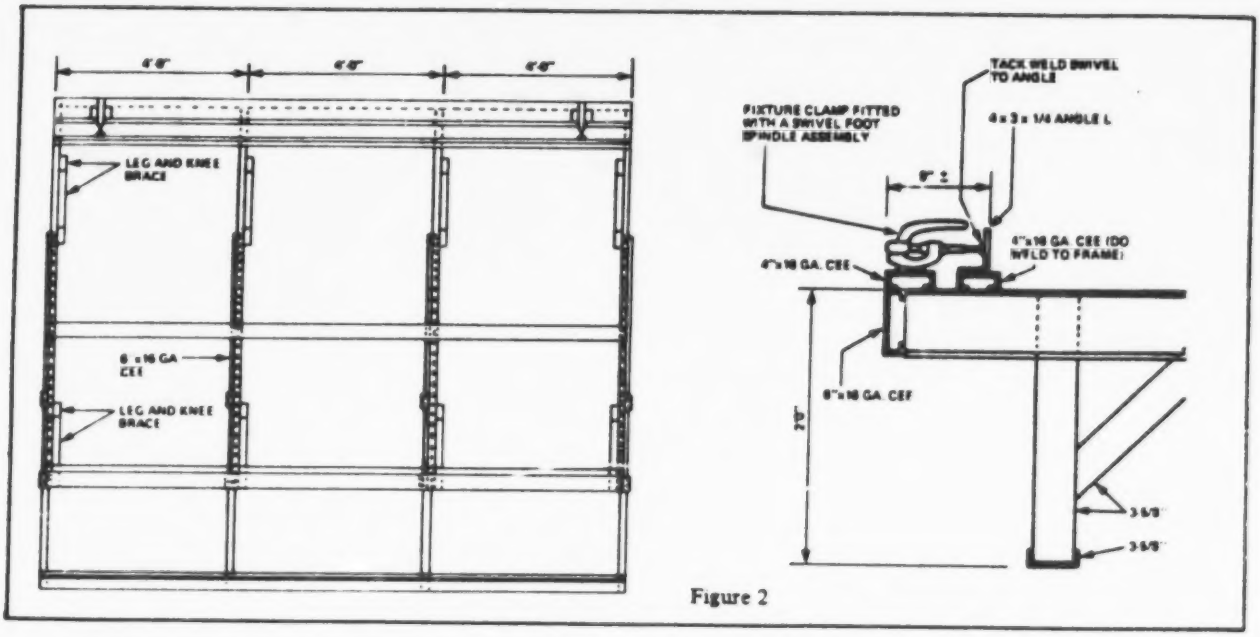

LEG AND KNEE BRACE
LEG AND KNEE BRACE
TACK WELD SWIVEL TO ANGLE
FIXTURE CLAMP FITTED WITH A SWIVEL FOOT SPINDLE ASSEMBLY
4 x 3 x 1/4 ANGLE L
4"x16 GA. CEE
8"x16 GA. CEE

Figure 2

IN GENERAL, YOU'LL NEED THE FOLLOWING SPACE, EQUIPMENT, AND TOOLS IN SETTING UP A FABRICATION SHOP:

A. Approximately 2,400 square foot (minimum) of floor space plus a yard to store materials and panels.
B. Raw storage area approximately 8' x 32' plus one horizontal rack.
C. Panel storage area approximately 12' x 40' minimum.
D. Jig fixtures. For commercial construction, recommended size is 12'-0" wide by 32'-0" to 40'-0" long. For residential construction, recommended size is 9'-6" wide by 32'-0" long.
E. Each table is fitted with four DE-STA-CO type fitting clamps or air/hydraulic cylinders to hold the track section seated properly over the studs.
F. Two MIG welders per fixture table with .045 wire, rectifiers, wire feeder guns and spot-time attachments.
G. Over-head track to mount the wire-feeder and spot timer.
H. One 3,200 R.P.M. radial arm saw fitted with a 16" metal cutting blade.
I. One forklift with a boom to move panels.
J. 30 ft. roller conveyor in 10 ft. sections.
K. Vise grips
L. Canvas shields for weld flash protection.
M. Paint touch-up equipment.
N. Miscellaneous tools as required.

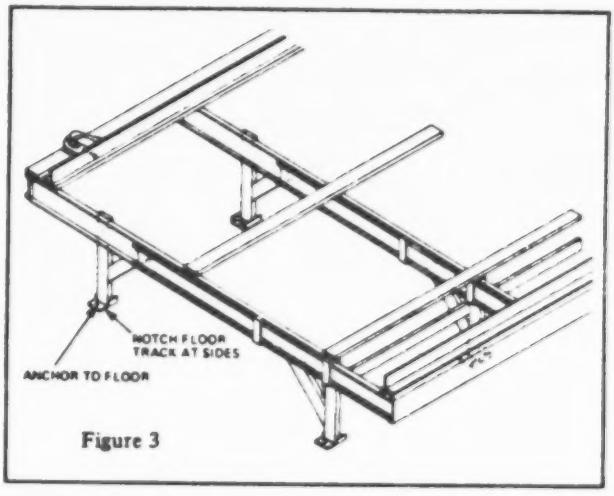


Figure 3

The fixture tables are the keys to successful assembly and fabrication. To minimize the investment, build them yourself from light gage steel framing materials.

Figures 2 and 3 show a fixture table extendable from 7'-6" to 12'-6" in width x 32'-0" long. This table should meet the requirements of most residential and commercial construction.

CUTTING

Light gage steel framing components may be ordered cut to length, however, some cutting by the contractor will probably be necessary for most projects.

The most efficient means of cutting is a radial arm saw fitted with either a friction type blade (280 - 300 teeth) or a reinforced abrasive cut-off wheel. The blade should be a minimum of 14" in diameter and 1/8" thick. The radial arm saw should produce 7.5 horsepower at 3,400 revolutions per minute.

Hand cutting should be done with a 3 horsepower, worm drive, hand-held circular saw equipped with a reinforced abrasive cut-off wheel. Power hack saws and band saws may also be used; however, they are usually too inefficient to be used on large projects.

Care must be exercised in the use of all cutting equipment. Blades should be shielded to prevent accidents, contain sparks, and protect the worker in case of blade fracture.

D. ERECTION

1. General Guidelines
2. Constructional Equipment
3. Procedure

ERECTION

Before doing any fabrication or erection, the contractor will usually submit fabrication and erection drawings to the architect and obtain his approval. After approval, careful site measurements should be taken so that any variations from the original plans can be allowed for. Care should be exercised at all times to avoid unnecessary damage through careless unloading, handling and erection of steel framing. Of course, steel framing should be set level and true and in a workman-like manner. During erection, care should also be exercised to avoid application of construction loads that exceed the carrying capacity of the studs and/or joists. Here are some additional important tips and suggestions:

1. Make certain that you use equipment of adequate capacity.
2. Don't depend on light gage framing to support any heavy equipment used in erection work.
3. All erection work must be level and to dimensions and elevations as indicated by plans, using leveling instruments and plumb bob. Report any discrepancies in plumbing or leveling to the architect.
4. Track must be securely anchored to the floor and overhead structure as indicated by plans, specifications, and code. Axially loaded studs must be seated squarely in the track, the stud web and flange abutting the track web, and all studs have to be plumbed, aligned, and securely attached to the flanges and webs of both upper and lower track. Studs must be positioned in track so as to be aligned directly below floor, roof, or ceiling framing members above. If not, headers must be provided.
5. Load bearing walls with steel studs and track must have a continuous, uniform base support underneath. Horizontal bridging, when required, should be installed before floor, roof or ceiling structure overhead is installed. The ends of the horizontal bracing must be securely anchored to suitable restraining columns or walls. Make welded connections by the fusion, resistance or fill process, in accordance with the latest recommended procedures and practices of the American Welding Society.
6. Provide stud walls at location indicated on plans as "Shear Walls" for frame stability and lateral load resistance. Then brace them as indicated on plans and specifications. Provide additional studs as needed to resist the vertical components as indicated on plans and specifications. Prefabricated panels and sub-assemblies must be square and may require bracing to resist racking. Exercise care in lifting prefabricated panels and sub-assemblies to prevent local distortion. When non-load bearing steel stud partitions abutt underside or are attached to load-bearing structural frame, the non-load bearing studs must be attached with slip connections to relieve stress from deflection of major framing.
7. At the corners and intersections of stud walls, provide a minimum of 3 studs, located so as to provide surfaces for attachment of all interior and exterior facings. Provide jack studs between all track and window sills; between window and door headers and top track; and free standing stair rails and elsewhere to furnish structural support. Make sure they're securely attached to supporting members.
8. Steel studs and joists must be installed and reinforced in accordance with the applicable load-span tables. Ends of steel joists have to be reinforced to adequately stiffen the joist web and transfer loads to the support as provided by plans and specifications.
9. Framing components must be cut so that they fit squarely against abutting members, and be held firmly in position until properly fastened in accordance with manufacturer's specifications. Wire tying of framing components in structural applications is not permitted.
10. Size and space joists as shown on drawings. Provide additional joists or "blocking" adjacent to exterior and interior walls, openings and elsewhere as necessary to provide support for ceiling construction as indicated by plans and specifications. Provide an additional joists under parallel partitions where the partition length exceeds one-half the joist span and for all floor and roof openings which interrupt one or more span members, unless otherwise noted. The ends of the joist must be fixed to prevent rotation and buckling. Steel joists may also be attached to other steel joists using steel joist hangers and/or clip angles as specified by manufacturer's specifications. The ends of the joists may be set in pockets formed in masonry block or concrete. These joists must be adequately reinforced, leveled, and grouted.
11. Both lateral and diagonal bracing must be provided for in accordance with the manufacturer's specifications or recommendations. Lateral bracing prevents the stud from bending about the minor axis due to axial loads and also prevents flange rotation due to uniform wind loading. Sheathing and wall board attached to both sides of the studs, if properly designed, can provide for horizontal bracing and resist diaphragm action.

    However, during construction, before wall sheathing is applied, floors and walls are often loaded with construction loads, thereby necessitating lateral bridging. If the sheathing is not designed to resist diaphragm action, then diagonal bracing must be used to resist racking loads imposed by wind or earthquake. Diagonal bracing may be steel straps which are stressed in tension when resisting racking. The straps extend from the bottom of one stud to the top of another, preferably at 45 to 60 degrees from the horizontal. The angle at which the strap is installed significantly affects the strap's ability to resist racking loads. Where required by the manufacturer's load span tables, the joist must be bridged with horizontal steel strapping fastened to the bottom flange and secured to a positive restraint at the ends. Refer to manufacturer's specifications for exact requirements for other suitable means of bridging.
12. During erection, steel cables with turn buckles may be installed in sufficient number to prevent distortion and damage to frame work due to wind or erection forces. These cables may also be used to plumb and align the work. The cables may be left in place until sufficient partitions have been placed to secure the lateral stability of the building.
13. Splices in axially loaded studs are not permitted.
14. Since the manufacturer cannot anticipate all of the various loadings which might be placed upon light-gage steel framing during the course of construction, the architect or project engineer should be consulted when necessary.

As an additional aid, the following is a checklist of equipment normally required for erecting steel framing:

1. Hoisting
   - A. Fork-lift.
   - B. Truck-mounted hydraulic crane with telescoping boom.
   - C. Truck-mounted, cable-operated crane.
   - D. On-slab winch type hoist.
2. Framing Attachment
   - A. Welding equipment
   - B. Bolting apparatus
   - C. Power driven fasteners
3. Safety Equipment
   - A. Barricades, fences and guardrails
   - B. Adequate planking, platforms, and guardrails for open shafts
   - C. Hard hats and safety glasses
   - D. Ladders conforming to state, local, and applicable ladder safety codes.
   - E. Scaffolding capable of supporting four times the expected load of men and material, guardrails on all exposed sides, and locking brakes.
   - F. Safety belts when required.

E. TECHNICAL SUPPORT

1. General Guidelines
2. Fire Resistance Ratings
3. Sound Ratings
4. Thermal Performance
5. Industry Standards & Practices
6. Outline Specifications

FIRE-RESISTANCE RATINGS OF

LOAD-BEARING STEEL STUD WALLS

WITH GYPSUM WALLBOARD PROTECTION WITH OR WITHOUT CAVITY INSULATION

AMERICAN IRON AND STEEL INSTITUTE

BUILDING CODE PROVISIONS

Building codes frequently require load-bearing walls to have a fire-resistance rating that is based on fire tests conducted in accordance with a specification of the American Society of Testing and Materials (ASTM) titled ASTM E119, *Standard Methods of Fire Tests of Building Construction and Materials*.

In the case of load-bearing walls, this test stipulates that they must: a) withstand fire exposure, under a specified loading, without structural collapse, thereby preventing flame passage through the wall, and b) prevent intra-wall transmission of heat that will ignite combustible materials on the unexposed side of the wall for which the indication of failure is defined as a 250°F (139°C) average temperature rise on the unexposed surface or 325°F (181°C) temperature rise at any one point. The fire exposure is followed by a fire and hose-stream test that is designed to evaluate the wall's resistance to the passage of the hose stream through the wall.

RESEARCH PROGRAM

American Iron and Steel Institute (AISI) sponsored a research program that sought to develop an analytical method that would make it possible to predict the structural behavior of cold-formed sheet-steel studs in load-bearing walls under the conditions set forth in the ASTM E119 Standard Fire Test.

This program called for full-scale fire tests designed to provide data on the effects of insulation, wallboard thickness, and loading on the fire-resistance ratings.

The entire study was conducted along two lines:

PHASE I consisted of seven full-scale fire tests conducted at Underwriters Laboratories, Inc. (UL). These investigations provided basic data as called for in the program. While this work was being carried out at UL, the Research Laboratory of the United States Steel Corp. (USS) was conducting small-scale tests on steel studs, to determine the effects of temperature on *yield strength* (Fy), *effective cross-sectional strength* (Q), and the *modulus of elasticity* (E).

PHASE II involved further work by the USS Research Laboratory to develop additional information for refining and substantiating the aforementioned data for temperatures up to approximately 1800°F (982°C). In addition, during this second *PHASE*, two other full-scale fire tests were run at UL. These included increased instrumentation to measure: a) the wall loading prior to and during the test, b) wall deflection at the point of structural failure, and temperature measurements of each steel stud.

CONSTRUCTION OF FIRE-TESTED ASSEMBLIES

The load-bearing wall assemblies were constructed in two ways—with and without insulation in the concealed space between cold-formed sheet steel studs spaced 24 inches o.c. Tests were run on studs faced with ½-inch or ⅝-inch thick Type X gypsum wallboard in one, two, or three layers. Design of the steel studs followed the recommendations of AISI *Specification for the Design of Cold-Formed Steel Structural Members*, 1968 Edition, assuming the steel studs were fully braced laterally by the gypsum wallboard.

Fire-resistance ratings, construction and material details are given in UL *Fire Resistance Directory* as Design No. U425 (Fig. 1). The ratings assigned to this Design are based on data from this test program along with data from three tests that had been carried out prior to the present work.

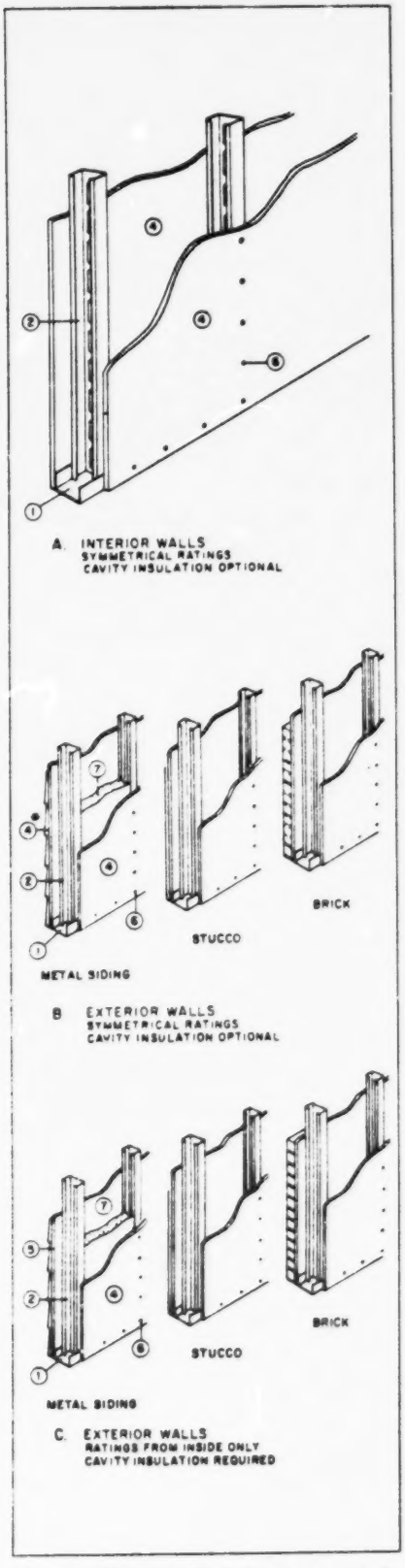


Figure 1. Details A, B, & C. Drawings and accompanying description of these three assemblies are adapted from Design No. U425 as given in the UL Fire Resistance Directory.

UL Fire Resistance Directory
Design No. U425

Interior Walls—Wallboard Protection Both Sides of Wall		
Rating	Number of Layers and Thickness of Boards in Each Layer	Percent of Design Load
45 min	*1 layer, ½ in. thick	100
1 hr	*1 layer, ⅝ in. thick	100
1½ hr	*2 layers, ½ in. thick	100
2 hr	*2 layers, ⅝ in. thick or	80
	*3 layers, ½ in. thick	100

*Ratings applicable to assemblies serving as exterior walls where Classified fire resistive gypsum sheathing type wallboard is substituted on the exterior face.

Exterior Walls—Wallboard Protection on Interior Side of Wall		
Rating	Number of Layers and Thickness of Boards in Each Layer	Percent of Design Load
45 min	1 layer, ⅝ in. thick	100
1 hr	2 layers, ½ in. thick	100
1½ hr	2 layers, ⅝ in. thick	100
2 hr	3 layers, ½ in. thick	100

1. Steel Floor and Ceiling Tracks—Top and bottom tracks of wall assemblies shall consist of steel members, min. No. 20 GSG (0.036 in. thick) galv. steel or No. 20 MSG (0.033 in. thick) primed steel, that provide a sound structural connection between steel studs, and to adjacent assemblies such as a floor, ceiling, and/or other walls. Attached to floor and ceiling assemblies with steel fasteners, spaced not greater than 24 in. o.c.

2. Steel Studs—Corrosion-protected steel studs, min. 3½ in. wide, min. No. 20 GSG (0.036 in. thick) galv. steel or No. 20 MSG (0.033 in. thick) primed steel, cold-formed, shall be designed in accordance with the current edition of the *Specification for the Design of Cold-Formed Steel Structural Members* by the American Iron and Steel Institute. All design details enhancing the structural integrity of the wall assembly, including the axial design load of the studs, shall be as specified by the steel stud designer and/or producer, and shall meet the requirements of all applicable local code agencies. The max. stud spacing of wall assemblies shall not exceed 24 in. Studs attached to floor and ceiling tracks with ½ in. long Type S-12 pan head, self-drilling, self-tapping steel screws on both sides of studs.

3. Lateral Support Members (Not shown)—Where required for lateral support of studs, support may be provided by means of steel straps, channels or other similar means as specified in the design of a particular steel stud wall system.

4. *Wallboard, Gypsum—Any gypsum wallboard bearing the UL1 Classification Marking as to Fire Resistance. Applied vertically with joints between layers staggered. Outer layer of three-layer construction may be applied horizontally. The thickness and number of layers and percent of design load for the 45 min, 1 hr, 1½ hr and 2 hr ratings are as follows:
See Wallboard Gypsum (CKNX) Category for names of Classified Companies.

5. Gypsum Sheathing and Exterior Facings—For exterior walls, single layer of ½ in. thick exterior regular gypsum sheathing applied vertically and attached to studs and runner tracks with 1 in. long Type S-12 bugle head screws spaced 12 in. o.c. along studs and tracks. Exterior facings consisting of aluminum siding, steel siding, brick veneer, or stucco attached to studs over gypsum sheathing and meeting the requirements of local code agencies. When a min. 3¾ in. thick brick veneer facing is used, the Exterior Wall Rating is applicable with exposure on either face. Brick veneer wall attached to studs with corrugated metal wall ties attached to each stud with steel screws, not more than each sixth course of brick.

6. Fasteners—Screws used to attach wallboard to studs: self-tapping bugle head sheet steel type, spaced 12 in. o.c. First layer Type S-12 by 1 in. long; second layer Type S-12 by 1⅜ in. long; third layer Type S-12 by 1⅝ in. long.

7. *Batts and Blankets—Placed in stud cavities of all exterior walls. May or may not be used in interior walls. Any glass fiber or mineral wool batt material bearing the UL Classification Marking as to Fire Resistance, of a thickness to completely fill stud cavity.
See Batts and Blankets (BZJZ) Category for names of Classified Companies.

8. Joint Tape and Compound—Vinyl or casein, dry or premixed joint compound applied in two coats to joints and screwheads of outer layer. Perforated paper tape, 2 in. wide, embedded in first layer of compound over all joints of outer layer.

*Bearing the UL Classification Marking

CONCLUSION

Figure 2 is a representation of the *load-ratio vs. failure-time* curves that provided some of the back-up data for the fire-resistance ratings given in UL Design No. U425. Here (Fig. 2), the load-ratio (P_T/P) is the ratio of the stud failure load at elevated (test) temperature, P_T, to that at room temperature, P. The horizontal line, a load-ratio of 12/23, represents the inverse of the safety factor used in room-temperature design of studs. The intersection points, on the horizontal line, made by the failure-time curves, represent the predicted fire-test failure time if the applied load of 100% of the design load at room temperature. Thus, dashed lines are used for the curves above this line because the allowable design loads at room temperature would be exceeded in this region. The vertical scale on the right is the ratio of the *allowable fire-test load* to the *allowable room-temperature load* calculated in accordance with the AISI *Specification for the Design of Cold-Formed Steel Structural Members*, 1968 Edition.

In using the fire-resistance ratings assigned to UL Design No. U425 the following should be noted:

- ☐ Loads are expressed as a percentage of the maximum load specified for steel studs by the given manufacturer.
- ☐ Steel studs must be designed in conformity with AISI *Specification for the Design of Cold-Formed Steel Structural Members* (current edition).

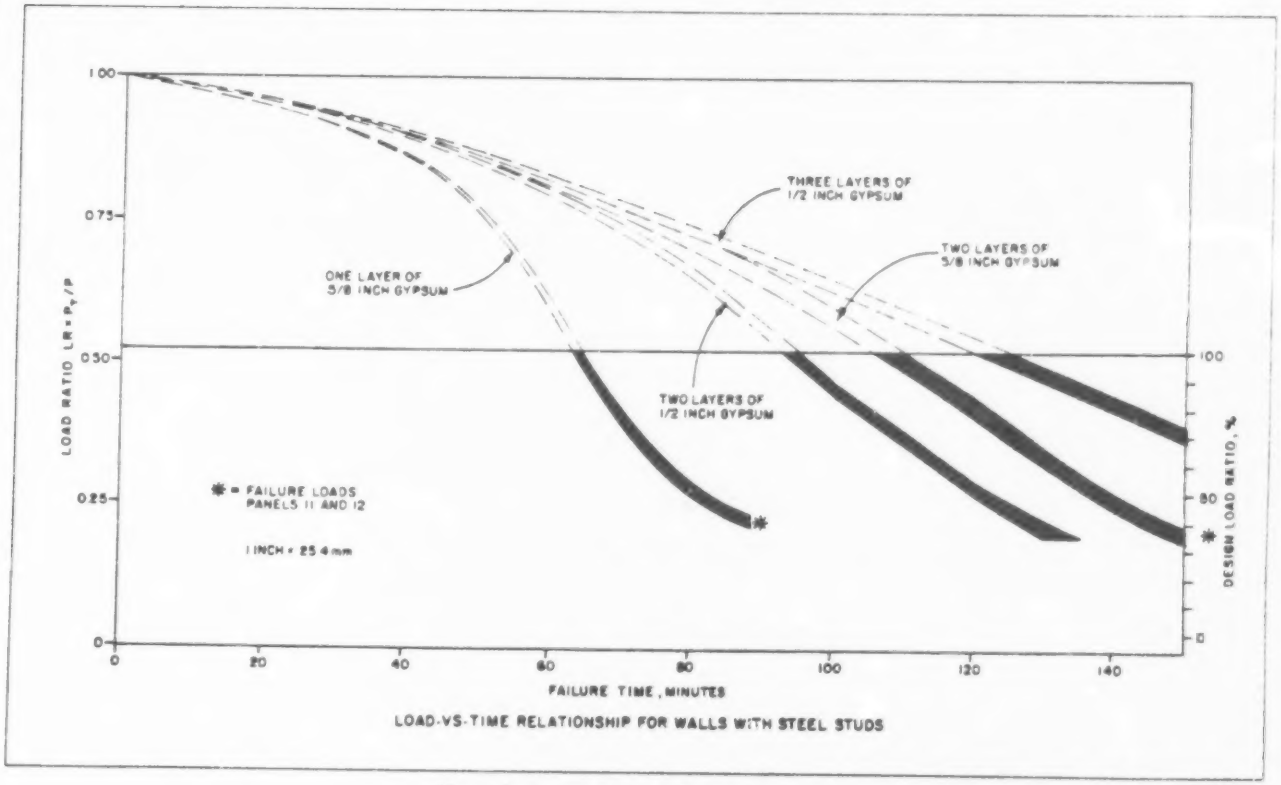


Figure 2. Curves of the load-vs.-time relationship for steel stud walls with various gypsum wallboard protections. Adapted from paper by K. H. Klippstein.[3]

- ☐ Insulation in the wall cavity does not affect the assigned fire-resistance rating of interior walls (Fig. 1, Detail A). UL fire tests demonstrated that a wall assembly *tested without insulation*, does not have its structural integrity reduced, nor are premature hot spots on the unexposed side of the wall produced.
- ☐ Ratings for interior walls are equally applicable to exterior walls (Fig. 1, Detail B). UL classified fire-resistive exterior gypsum wallboard sheathing may be substituted for gypsum wallboard on the exterior wall face. Ratings for such exterior walls are applicable for either wall face.
- ☐ If UL classified fire-resistive, water-resistant gypsum wallboard is substituted for the non-water-resistant type on interior locations, e.g. bathrooms, the assigned rating remains unchanged.
- ☐ For exterior walls having the specified type of brick veneer, the fire-resistance rating applies to either side of the wall (Fig. 1, Detail C).
- ☐ Fire-resistive ratings for *load-bearing walls* can be applied to *non-load-bearing walls*.
- ☐ Exterior wall facings, if different from those described in the UL Directory, may be acceptable if they are secured to the steel framing in a manner acceptable to the authority with jurisdiction (Fig. 1, Detail B or C).

REFERENCES

1. "Standard Methods of Fire Tests of Building Construction and Materials," American Society for Testing and Materials, *ASTM E119-79*.
2. "Specification for the Design of Cold-Formed Steel Structural Members," American Iron and Steel Institute, 1968 Edition.
3. Klippstein, K. H., "Behavior of Cold-Formed Steel Studs in Fire Tests," Proceeding, Fifth Specialty Conference, University of Missouri–Rolla, November 1980.

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This publication was prepared by the
SUBCOMMITTEE ON FIRE TECHNOLOGY of the
COMMITTEE ON CONSTRUCTION CODES AND STANDARDS

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Washington, D.C. 20036

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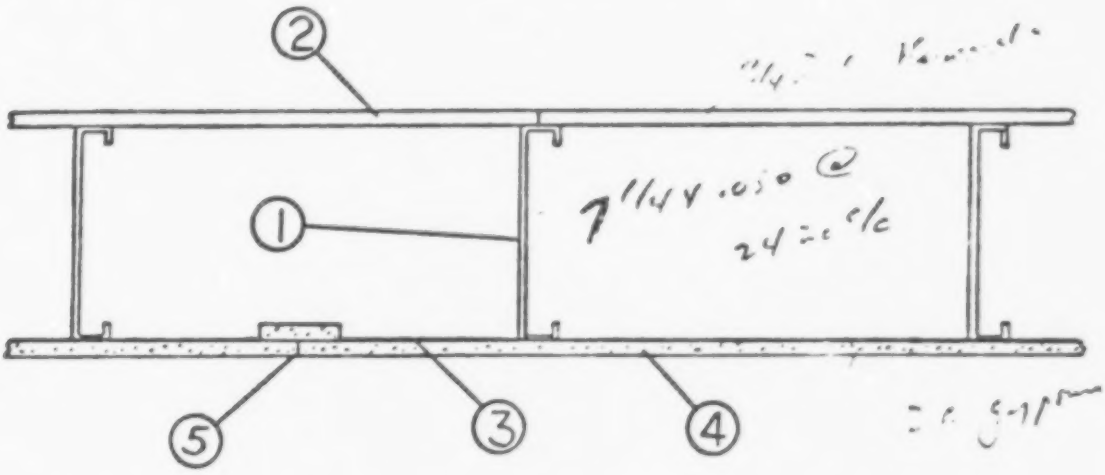
CONSTRUCTION SUMMARY
DESIGN FC-184 - 45 MINUTE



1. Steel Joists - 18 ga. (0.050 in.) galvanized steel channel shape, 7 1/4 in. deep with flanges of 1 3/4 and 1 7/8 in., spaced 24 in. o.c. Members manufactured by United States Steel Corporation and designated as Super C steel joist. Channel shape clip installed at each end of the joists for securing joist to supports.

2. Wood Floor - 3/4 in. thick plywood, minimum grade to be underlayment with long edges tongue and groove, and conforming to P.S. 1-66. Plywood face grain to be perpendicular to joist with end joints staggered 4 ft with adjacent rows. Secure to joist with 1 15/16 in. long Type S-12 screws, spaced 12 in. o.c. at end joints and intermediate supports.

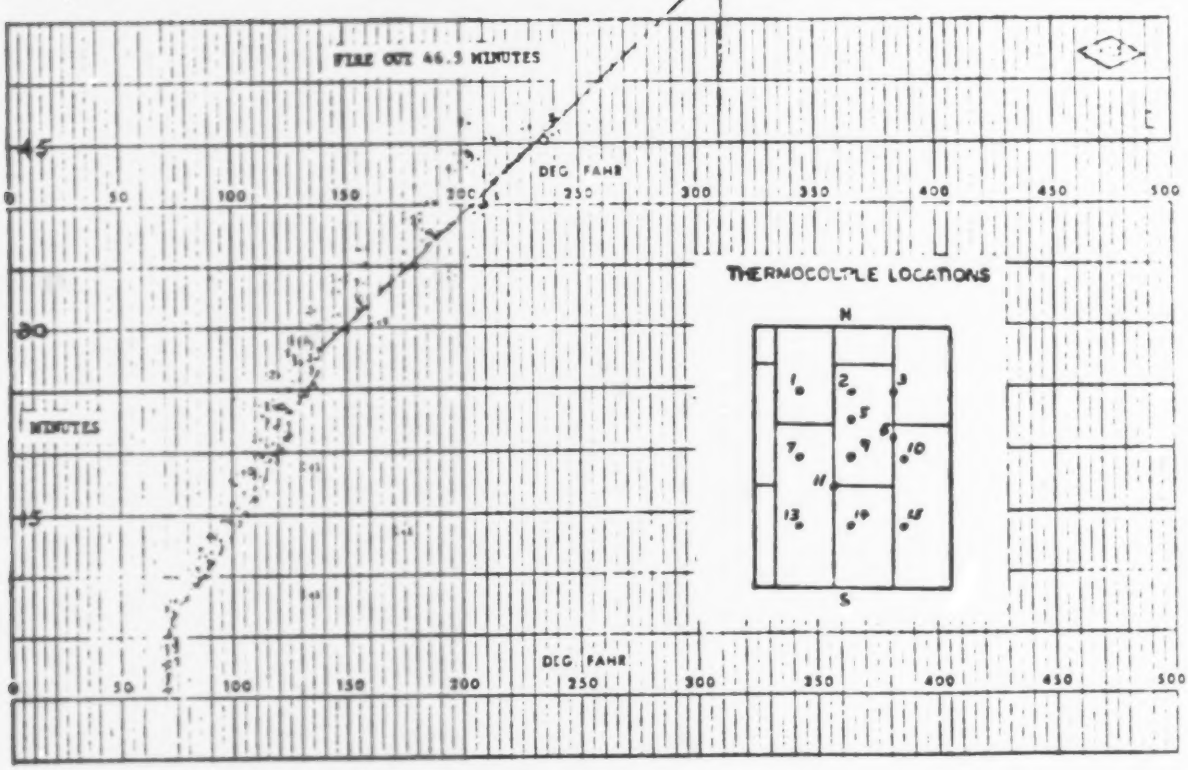
3. Bridging - Continuous 18 ga (0.048 in.) galvanized steel flat strap 2 in. wide placed perpendicular to joist and secured to bottom flange at center of span.

4. Wallboard Ceiling - One layer of 5/8 in. Fire-Shield gypsum wallboard designated as Type FSW, manufactured by National Gypsum Company and Factory Mutual approved. Apply the wallboard perpendicular to the joists with butt joints midway between the joist and secure to joist with 1 in. long Type S-12 drywall screws spaced 12 in. o.c. Attach a 6 in. wide strip of 5/8 in. thick wallboard to the butt joints with 1 1/2 in. long Type G screws spaced 12 in. o.c., set back 2 in. from the joint, and overlap adjacent rows of wallboard 6 in.

5. Joint Treatment - Cover all wallboard joints with paper tape and two coats of joint compound. Cover screw heads with two coats of joint compound.

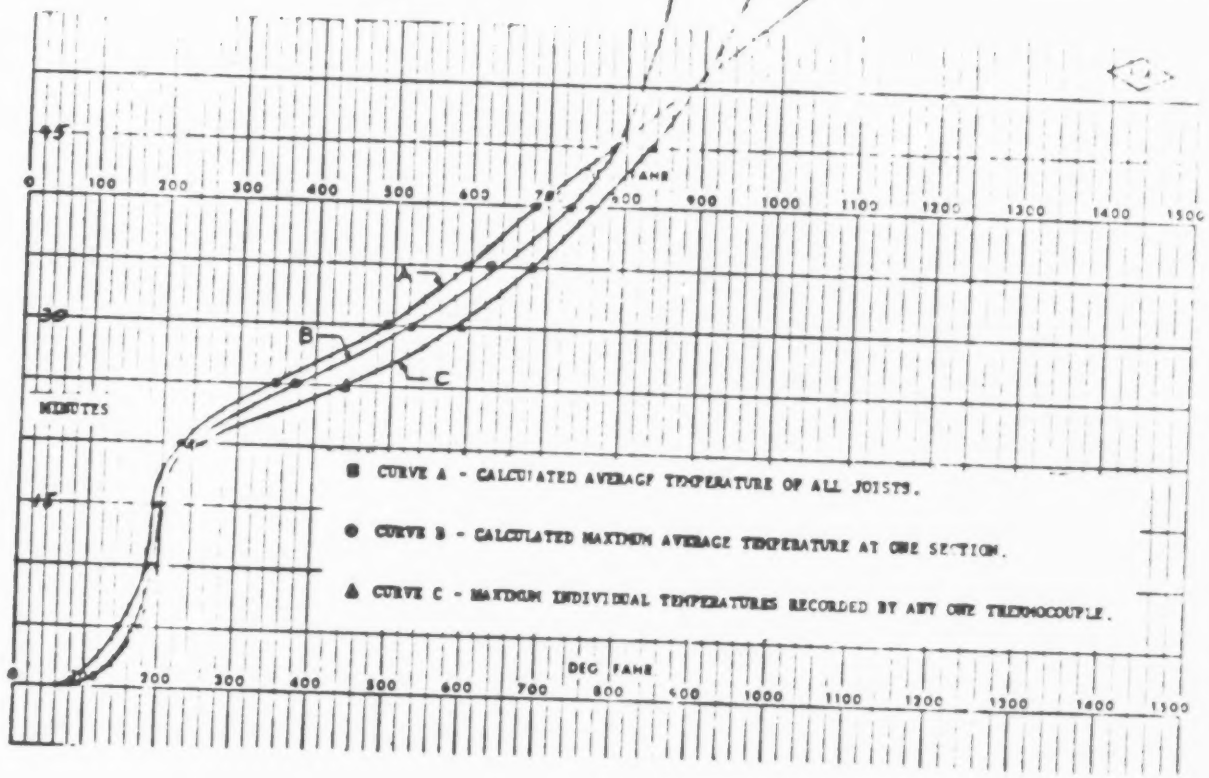
UNEXPOSED SURFACE TEMPERATURES
FIRE ENDURANCE TEST
NOVEMBER 1, 1972
U.S. STEEL CORP.

ILLUSTRATION 7



STEEL JOIST TEMPERATURES
FIRE ENDURANCE TEST
NOVEMBER 1, 1972
U.S. STEEL CORP.

ILLUSTRATION 8



ASTM E119-76

ONE HOUR FIRE ENDURANCE TEST

UNRESTRAINED FLOOR/CEILING ASSEMBLY
CHANNEL SHAPE STEEL JOIST
LIGHTWEIGHT CONCRETE FLOOR AND GYPSUM WALLBOARD CEILING
DESIGN FC245-ONE HOUR-SERIAL NO. 29135 (4610)

conducted for

Metal Lath/Steel Framing Association

by Factory Mutual Research

INTRODUCTION

This summary report describes the construction, materials and conclusions of a fire endurance test conducted on a floor-ceiling assembly. The floor consisted of 6 in. (152 mm) deep channel shape, steel joist spaced 24 in. (610mm) o.c. with corrugated steel deck and lightweight concrete floor. The ceiling was a single layer of 1/2 in. (12.7mm) thick gypsum wallboard fastened to resilient furring channels.

The object of this investigation was to establish a fire resistance classification for a floor-ceiling assembly, erected and constructed of materials conforming in quality and physical properties to those herein described by means of a fire endurance test conducted in accordance with the Standard for Fire Tests of Building Construction and Materials ASTM Designation E119-76, (NFPA No. 251). The test was conducted on January 27, 1977.

The tests showed the described construction meets the requirements for a one hour fire resistance rating as an unrestrained assembly.

As the test assembly was not restrained against thermal expansion, the conditions of acceptance for establishing this rating was based on the ability of the assembly to sustain the applied design load and retard excessive temperature transmission during the fire exposure for the classification period. Steel joist temperature limitations do not apply to this assembly as constructed based on Paragraph 24.3 of the ASTM E119-76 Standard.

Metal Lath/Steel Framing Association
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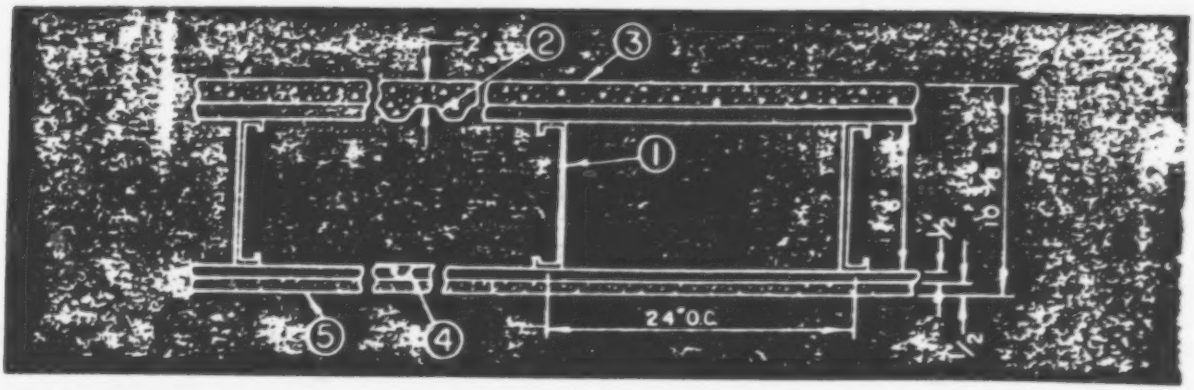


CONSTRUCTION SUMMARY: FLOOR CEILING ASSEMBLY

1 STEEL JOISTS: 18 ga. (0.05 in., 1.27 mm) painted steel "C" shape, 33,000 psi (227 N/M^2) minimum yield strength, with 6 in. (152 mm) deep web, 1-5/8 in. (41 mm) flanges, and 9/16 in. stiffeners and spaced 24 in. (610 mm) o.c. The joists were erected with 6-3/16 in (157 mm) deep channel shaped track using 5-3/4 in. (146 mm) long 16 ga. (1.50 mm) steel angle clips. The clips were welded to the joists and track with two nominal 1 in. (25 mm) long welds.

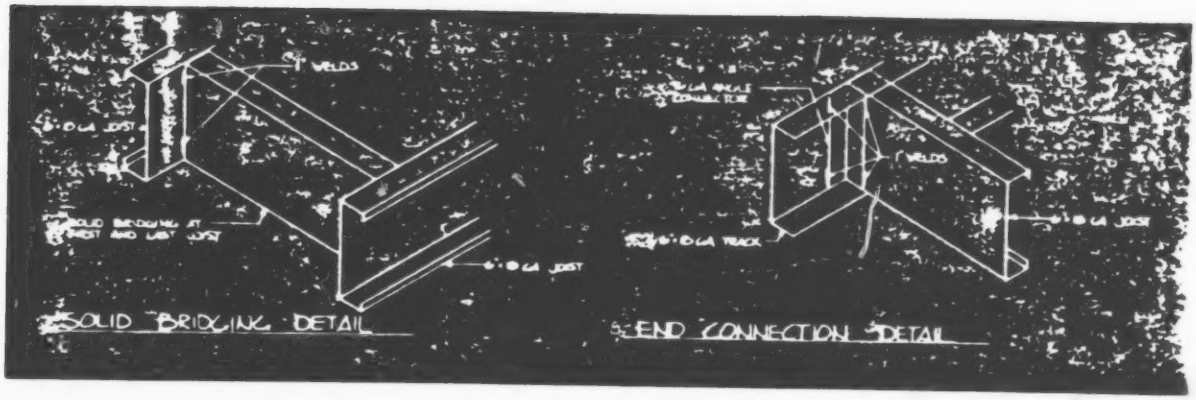
2 METAL DECK: 24 ga. (0.026 in., 0.66 mm) galvanized steel form deck with 1-5/16 in. (33 mm) deep corrugations spaced 5 in. (127 mm) o.c. Deck secured to the joists with 3/4 in. (19 mm) long HWH screws having 0.125 in. (3.2 mm) diameter shank, 0.495 (12.6 mm) diameter washer. Fasteners spaced 10 in. (254 mm) o.c. End joints lapped the joists 3 in. (76 mm) and were staggered 4 ft. (1.22 mm) between adjacent rows.

3 LIGHTWEIGHT CONCRETE: Elastizell controlled density concrete 2 in. (51 mm) thick as measured from the top of the steel deck corrugations. The concrete was by weight 1 part Portland cement to 3 parts sand which was mixed wtih 5.3 gal. (20 dm^3) water per 94 lb. (42.5 kg) bag of cement. The Elastizell foam was added to achieve a design density of 105 lb./ft.^{3}(1682 kg/m^3).

4 RESILIANT FURRING CHANNELS: Hat shaped members 2-3/4 in. (70 mm) wide x 1/2 in. (13 mm) deep formed of 25 ga. (0.023 in., 0.58 mm) thick galvanized steel. Furring channels installed perpendicular to the joists and spaced 24 in. (610 mm) o.c. Additional lengths of channels located 12 in. (304 mm) o.c. at ceiling butt joint locations. Fasten channels with two 3/8 in. (10 mm) long Type S-12 pan head screws at each joist. End joints are nested and occur at the joist.

5 WALLBOARD CEILING: One layer of 1/2 in. (12.7 mm) thick Firecode C gypsum wallboard designated as Type FC and manufactured by United States Gypsum Co. Apply the wallboard perpendicular to the resilient furring channels and fasten with 1 in. (25 mm) long Type S drywall screws spaced 12 in. (305 mm) o.c. Butt joints occur at the furring channels located 12 in. (305 mm) o.c. and were staggered 4 ft. (1.2 mm) between adjacent rows. Long joint screws are set back 2 in. (51 mm) from the edges of the wallboard. An additional screw placed through the wallboard adjacent to the butt joints into the butt joint furring channel. All exposed wallboard joints were reinforced with paper tape and covered with joint compound. Exposed screw heads were covered with joint compound.

ONE HOUR FIRE ENDURANCE TEST



CONCLUSIONS

FIRE RESISTANCE PROPERTIES

The unrestrained floor-ceiling assembly of the construction described herein afforded one hour protection against passage of flame and transmission of heat while the joists were subjected to their design load. The test was terminated at 73 minutes.

No passage of flame, smoke or hot gases through the test assembly occurred during the 60-minute classification period. The transmission of heat through the assembly did not raise the average temperature of the unexposed surface over the allowable 250°F (139°C) temperature rise limit or 325°F (180°C) for a single temperature reading during the classification period.

Steel joist temperature limitations do not apply to this assembly as constructed based on requirements under Paragraph 24.3 of the ASTM E119-76 Standard.

PRACTICABILITY

The assembly described herein is practical for its intended use and can be installed without difficulty.

To obtain the desired protection it is necessary to specify the composition and thickness of materials and the methods of construction as described in this report.

CONFORMITY

This construction was tested as an unrestrained assembly in accordance with the Standard for Fire Tests of Building Construction and Materials ASTM E119-76, (NFPA No. 251) and based on the conditions of acceptance under Paragraph 24.3 of the Standard.

A limited number of copies of the full report are available from the Association office.

ASTM E119-73

TWO HOUR FIRE ENDURANCE TEST

UNRESTRAINED FLOOR/CEILING ASSEMBLY
CHANNEL SHAPE STEEL JOIST
LIGHTWEIGHT CONCRETE FLOOR AND GYPSUM WALLBOARD CEILING
DESIGN FC224-TWO HOUR-SERIAL NO. 24676.4 (4610)

conducted for
Factory Mutual Research

printed by
Metal Lath/Steel Framing Association

INTRODUCTION

This report describes the construction, the test procedure, and lists the results of a fire endurance test conducted on a floor-ceiling assembly. The floor consisted of 7-1/4-in. deep channel shape, steel joist spaced 24-in. o.c. with corrugated metal deck and a 2810 psi strength concrete floor. The ceiling consisted of a double layer of 5/8-in. thick Type X gypsum wallboard.

The object of this investigation was to establish a fire resistance classification for a floor-ceiling assembly, erected and constructed of materials conforming in quality and physical properties to those herein described, by means of a fire endurance test conducted in accordance with the Standard for Fire Tests of Building Construction and Materials ASTM Designation E119-73, (NFPA No. 251). The test was conducted September 19, 1975.

The tests showed the described construction meets the requirements for a two hour fire resistance rating as an unrestrained assembly.

As the test assembly was not restrained against thermal expansion, the conditions of acceptance for establishing this rating was based on the ability of the assembly to sustain the applied design load and retard excessive temperature transmission during the fire exposure for the classification period. Steel joist temperature limitations do not apply to this assembly as constructed based on Paragraph 23.3 of the ASTM E119-73 Standard.

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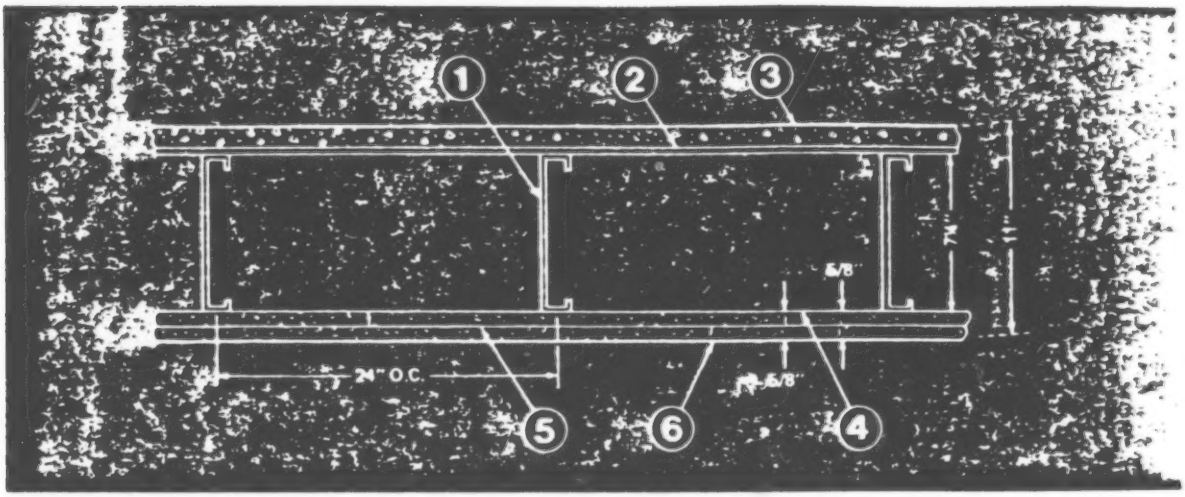


CONSTRUCTION SUMMARY: FLOOR CEILING ASSEMBLY

1 STEEL JOISTS: 18 ga. (0.052-in.) galvanized steel channel shape, 7 1/4-in. deep with flanges of 1 3/4 and 1 7/8-in., spaced 24-in. on center. Channel shape clip installed at each end of the joists for securing joist to

2 METAL DECK: 28 ga. (0.016-in.) galvanized steel form deck, with 9/16-in. deep corrugations spaced 2 1/2-in. on center. Deck secured to the joists with 3/4-in. long HWH Tek screws. (0.154-in. diameter shank, 0.403-in. diameter washer) spaced 12-in. on center. End joints staggered 4-ft. between adjacent rows.

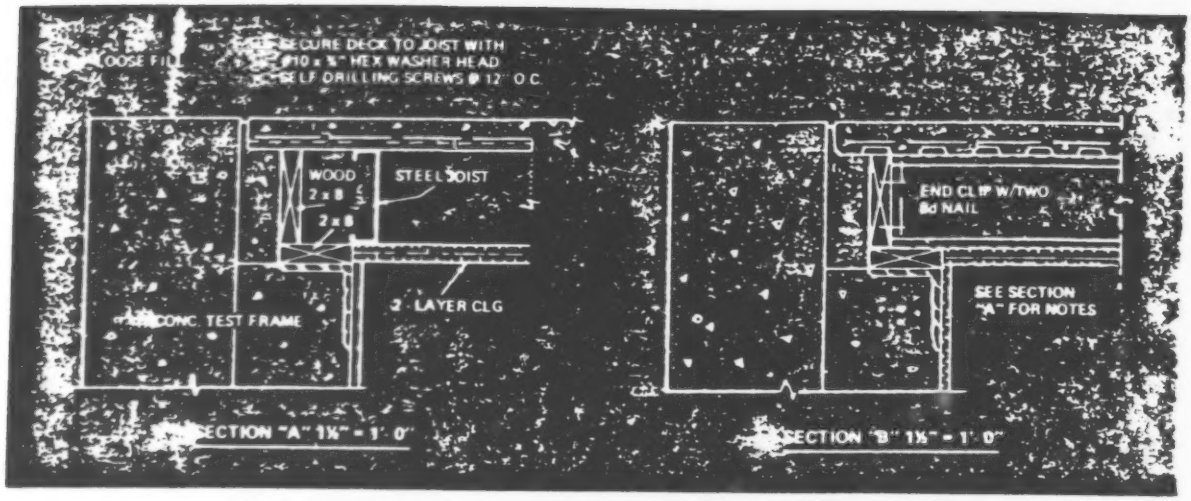
3 CONCRETE: 1:2.75:3.75 cement-sand-gravel mix, 2800 psi strength. Concrete depth 2 1/2-in. as measured to the lower flange with No. 10 SWG steel wire, 6 by 6 mesh.

4 BRIDGING: Continuous 18 ga.(.052-in.) galvanized steel flat strap 2-in. wide placed perpendicular to joist and secured to bottom flange at center of span, splices lapped two joists.

5 WALLBOARD CEILING: Two layers of 5/8-in. thick Fire-Shield gypsum wallboard, designated as Type FSW, manufactured by National Gypsum Company. Apply wallboard perpendicular to the joists with butt joints midpoint between the joist and secure the first layer with 1-in. long Type S-12 drywall screws spaced 12-in. on center and 3-in. from the edges. Stagger butt joints 2-ft. between adjacent rows. Second layer installed perpendicular to joist with joints staggered 2-ft. from joints in the first layer. Secure with 1 7/8-in. long Type S-12 drywall screws spaced 12-in. on center and 2-in. from edges. Secure end joints to first layer of wallboard with 1 1/2-in. long Type G drywall screws spaced 12-in. on center and set back 2-in. from the joints.

6 JOINT TREATMENT: Exposed wallboard joints cover with paper tape and two coats of joint compound. Exposed screw heads cover with two coats of joint compound.

TWO HOUR FIRE ENDURANCE TEST



CONCLUSIONS

FIRE RESISTANCE PROPERTIES

The unrestrained floor-ceiling assembly of the construction described herein afforded two hour protection against passage of flame and transmission of heat while supporting its design load. The test was terminated at 132 minutes.

No passage of flame, smoke, or hot gases through the test assembly occurred during the 120 minute classification period. The transmission of heat through the assembly did not raise the average temperature of the unexposed surface over the allowable 250°F (139°C) temperature rise limit or 325°F (180°C) for a single temperature reading during the classification period.

Steel joist temperature limitations do not apply to this assembly as constructed based on requirements under Paragraph 23.3 of the ASTM E119-73 Standard.

PRACTICABILITY

The assembly described herein is practical for its intended use and can be installed without difficulty. To obtain the desired protection it is necessary to specify the composition and thickness of materials and the methods of construction as described in this report.

CONFORMITY

This construction was tested as an unrestrained assembly in accordance with the Standard for Fire Tests of Building Construction and Materials ASTM E119-73, (NFPA No. 251) and based on the conditions of acceptance under Paragraph 23.3 of the ASTM Standard.

A limited number of copies of the full report are available from the ML/SFA office.

ACKNOWLEDGEMENT

The Metal Lath/Steel Framing Association recognizes that this test was originally conducted by United States Steel Corporation.

TWO HOUR FIRE ENDURANCE TEST

Stronger, more efficient USG Light Steel Framing

USG Light Steel Framing is an ideal structural material for load bearing or non-load bearing construction in many building types requiring fire protection plus these extra features:

Versatility Dual purpose sections - for studs and joists - available in many sizes and thicknesses provide economical framing for buildings up to four stories high

Lightweight - Engineered high strength-to-weight ratio results in lighter weight sections that are easily handled by one man, fast to install. Ground-level panel assembly and shop-fabricated panels becomes practical

Low in-place cost - Many features assure rapid installation saving time and money. Wide 24 in. spacing keeps material and handling costs low. Custom cut lengths minimize scrap and labor-intensive job cutting. Color coding speeds identification, simplifies job site sorting and inspection. Factory punched holes permit easier installation of pipe and conduit. Wide readily located flanges simplify screw attachment of surfacing materials

Superior performance Framing is noncombustible which may result in lower insurance cost. Assemblies offer up to 2-hr fire resistance ratings for interior partitions, exterior walls and floor/ceilings (see test data below). Framing meets model building codes and HUD requirements

Predictable profits Prices for steel are relatively stable making cost estimates more reliable and profits more consistent

Effective corrosion-resistance Light steel framing members are fabricated from hot dip galvanized steel; the finish meets ASTM A525 coating class G-60. Coating with zinc is one of the most effective and economical methods to control steel corrosion during shipment, erection and use. The zinc covers the steel with a barrier coating which minimizes rusting and protects it from air, moisture, acids, salts and other contaminants. If the coating is scratched or cut, the zinc, being anodic to steel, protects the exposed base metal by galvanic action

Compare these features:

Load-bearing joists

		USG Steel Joist		2x10 Wood Joist	
		925SJ14	95SJ18	Douglas Fir	Southern Pine
Weight	lb/lin-ft	3.50	[illegible]	3.0	3.9
	kg/m	5.21	4.[illegible]	5.8	5.8
Joist Spacing	in	24	16	12	16
	mm	610	406	305	406
Max. Allowable Simple Span*		19'6"	21'7"	18'6"	18'-0"
		5.9 m	6.6 m	5.6 m	5.5 m
Dimensionally stable		Yes	Yes	No	No
Noncombustible		Yes	Yes	No	No
Knot free		Yes	Yes	No	No
Termite free, vermin proof		Yes	Yes	No	No
Hot resistant		Yes	Yes	No	No
Cut to length		Yes	Yes	No	No
Predictable pricing		Yes	Yes	No	No

*Based on 10 psf dead load and 30 psf live load

steel studs vs concrete block

		USG Steel Studs	8 Concrete Block
		35SJ22, 24 o.c.	Lightwt. Agg.
Weight	lb/ft²	5.4	36.0
	kg/m²	26.4	176
Wall Thickness	in	3½ plus finish	8 plus finish
	mm	89 plus finish	204 plus finish
Trades Required		carpenter	mason & carpenter
Noncombustible		Yes	Yes
All-weather Installation		Yes	No
Prefabrication and Panelization		Yes	No
Simple Electrical Installation		Yes	No
Easily Insulated		Yes	No

Fire test data

fire rating	description & test no.	STC	IIC	acoustical performance description & test no.
1 hr. est.	⅝" SHEETROCK® Brand FIRECODE® "C" gypsum panels - USG 75SJ18 steel joists 24" o.c. - 2 x [illegible] core fir on corrug. steel deck - gypsum panel ceiling att. to joists with 1" Type S 12 screws 12" o.c. - joists fin. - est. fire rating based on [illegible] laboratory test	45		Based on RC-1 resilient chan. 24" o.c. - KAL-443536 A
			70	Based on carpet & pad - KAL-443535
1 hr. (Design No. [illegible])	⅝" SHEETROCK® Brand FIRECODE® "C" gypsum panels - USG 75SJ18 steel joists, 24" o.c. - ¾" T & G plywd. floor att. to joists with Type S 12 screws 6" o.c. at edges and perim., 10" o.c. in field - dbl. layer gypsum panel clg. and dbl. layer gyp. [illegible] wrap around beam - joints exp. - includes unrestrained beam - UL Des. L524	39		USG-760105 B
		43		Based on [illegible] USG-760310
			56	Based on carpet & pad - USG-760105
			60	Based on carpet & pad [illegible] attic blanket* - USG-760405

*[illegible] by effective fire rating

fire rating	fire-rated construction – floor/ceiling description & test no.	acoustical performance STC	IIC	description & test no.	
1½ hr	Resilient ⅝" SHEETROCK Brand FIRECODE "C" gypsum panels – USG 95SJ16 steel joists 24" o.c. – ¾" T&G plywd flr. att. to joists with Type S-12 screws 24" o.c. – dbl. layer gypsum panel ceiling att. to RC-1 chan. screw att. to joists 16" o.c. – base panels att. with 1" Type S screws 24" o.c. – face panels att. with 1⅝" Type G screws 8" o.c. at butt joints; 1⅝" Type S screws 12" o.c. in field; joints fin. **UL Des L527**	48 51		**USG-771101** Based on carpet & pad: **SA-781110**	C
2 hr. est.	⅝" SHEETROCK Brand FIRECODE "C" gypsum panels – USG 75SJ18 steel joists 24" o.c. – ¾" T&G flr. over comp. steel deck – dbl. layer gypsum panel ceiling – base panels att. with 1" Type S-12 screws 12" o.c. – face panels att. with 1⅝" Type S-12 screws 12" o.c. – joints stag. and fin. – est. fire rating based on witnessed laboratory test	44 47	73	**KAL-443533** Based on carpet & pad: **KAL-443680** Based on RC-1 resil. chan. 24" o.c. – **KAL-443534**	D

fire rating	fire-rated construction – interior walls description & test no.	acoustical performance STC	description & test no.	
45 min.	½" SHEETROCK Brand FIRECODE "C" gypsum panels – 35SJ20 studs 24" o.c. – panels appl. vert. & att. with 1" Type S-12 screws 12" o.c. – joints fin. **load bearing up to 100% allowable stud axial load – UL Des U425**	44	Est. ±3 STC based on computer simulation using 3" sound atten. blankets	E
1 hr	⅝" SHEETROCK Brand FIRECODE gypsum panels – 35SJ20 studs 24" o.c. – panels appl. vert. & att. with 1" Type S-12 screws 12" o.c. – joints fin. **load bearing up to 100% allowable stud axial load – UL Des U425**	44	Based on 3" sound atten. blankets: **USG-801019**	F
1½ hr	Dbl. layer ⅝" SHEETROCK Brand FIRECODE "C" gypsum panels – 35SJ20 studs 24" o.c. – panels appl. vert. base layer att. with 1" Type S-12 screws 12" o.c. face layer att. with 1⅝" Type S-12 screws 12" o.c. – joints fin. – **load bearing up to 100% allowable stud axial load – UL Des U425**	52	Est. ±STC based on computer simulation using 3" sound atten. blankets	G
2 hr	Dbl. layer ⅝" SHEETROCK Brand FIRECODE gypsum panels – 35SJ20 studs 24" o.c. – panels appl. vert. base layer att. with 1" Type S-12 screws 12" o.c. face layer att. with 1⅝" Type S-12 screws 12" o.c. – joints fin. – **load bearing up to 80% allowable stud axial load – UL Des U425**	50	Est. ±STC based on computer simulation using 3" sound atten. blankets	H

fire rating	fire-rated construction – exterior walls description & test no.	
45 min.	½" FIRECODE gypsum sheathing exterior – 35SJ20 studs 24" o.c. – ½" SHEETROCK Brand FIRECODE "C" gypsum panel interior – panels appl. vert. & att. with 1" Type S-12 screws 12" o.c. – **load bearing up 100% allowable stud axial load – UL Des U425**	I
45 min.*	½" gypsum sheathing exterior – 35SJ20 studs 24" o.c. – ½" SHEETROCK Brand FIRECODE gypsum panel interior – panels appl. vert. & att. with 1" Type S-12 screws 12" o.c. – **load bearing up to 100% allowable stud axial load – UL Des U425**	J
1 hr	⅝" FIRECODE gypsum sheathing exterior – 35SJ20 studs 24" o.c. – ⅝" SHEETROCK Brand FIRECODE gypsum panel interior – panels appl. vert. & att. with 1" Type S-12 screws 12" o.c. – **load bearing up to 100% allowable stud axial load – UL Des U425**	K
1½ hr	Dbl. layer ½" FIRECODE gypsum sheathing exterior – 35SJ20 studs 24" o.c. – dbl. layer ½" SHEETROCK Brand FIRECODE gypsum panel interior – base layers att. with 1" Type S-12 screws 12" o.c. – face layers att. with 1⅝" Type S-12 screws 12" o.c. – **load bearing up to 100% allowable stud axial load – UL Des U425**	L
1½ hr.*	½" gypsum sheathing exterior – 35SJ20 studs 24" o.c. – dbl. layer ⅝" SHEETROCK Brand FIRECODE gypsum panel interior – base layers att. with 1" Type S-12 screws 12" o.c. face layers att. with 1⅝" Type S-12 screws 12" o.c. – **load bearing up to 100% allowable stud axial load – UL Des U425**	M
2 hr	Dbl. layer ⅝" FIRECODE gypsum sheathing exterior – 35SJ20 studs 24" o.c. – dbl. layer ⅝" SHEETROCK Brand FIRECODE gypsum panel interior – base layer att. with 1" Type S-12 screws 12" o.c. face layer att. with 1⅝" Type S-12 screws 12" o.c. – **load bearing up to 80% allowable stud axial load – UL Des U425**	N

* [illegible] load bearing

...re ratings • typical examples

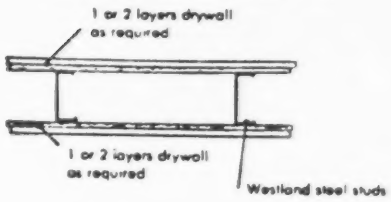
	A Non-Load Bearing Walls (Interior)	U.L.C. Design No.
...	1 layer 5/8" gypsum wallboard 1 layer 1/2" gypsum wallboard 2-1/2" steel studs 1 layer 1/2" gypsum wallboard 1 layer 5/8" gypsum wallboard	W404
1 1/2 hr	2 layers 1/2" gypsum wallboard 2-1/2" steel studs 2 layers 1/2" gypsum wallboard	W401
1 hr	1 layer 1/2" gypsum wallboard 1 layer 3/8" gypsum wallboard 2 1/2" steel studs 1 layer 3/8" gypsum wallboard 1 layer 1/2" gypsum wallboard	W402

	B Load Bearing Walls (Exterior)	U.L. Design No.
... hr	1 layer 1/2" gypsum wallboard 5/8" or 6" steel studs exterior facing	U418
1 hr	2 layers 1/2" gypsum wallboard 3 5/8" or 6" steel studs exterior facing	U418
45 min	1 layer 1/2" gypsum wallboard 3 5/8" or 6" steel studs exterior facing	U418

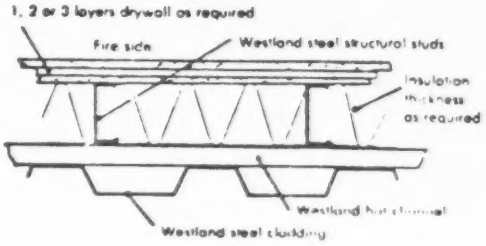
NOTE 1. There are no [illegible] by U.L.C. for fire rated load bearing walls.

2. Although each [illegible] only is detailed, [illegible] tests have been [illegible] from [illegible] to obtain these ratings.

Interior non-load bearing wall



Exterior load bearing wall


1, 2 or 3 layers drywall as required
Fire side
Westland steel structural studs
Insulation thickness as required
Westland steel cladding

Imperial-metric conversions

[illegible] metric [illegible]

Imperial Metric Conversion Factors

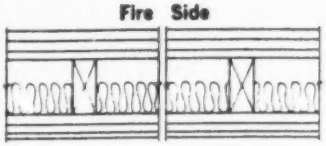
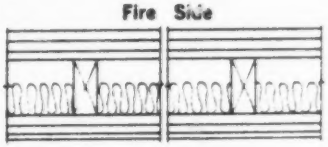
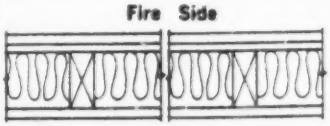
1. To convert inches (in.) to centimetres (cm), multiply by 2.540
2. To convert inches² (in²) to centimetres² (cm²), multiply by 6.452
3. To convert inches³ (in³) to centimetres³ (cm³), multiply by 16.387
4. To convert inches⁴ (in⁴) to centimetres⁴ (cm⁴), multiply by 41.623
5. To convert pounds per foot (lbs /ft.) to kilograms per metre (kg/m), multiply by 1.488
6. To convert pounds per square inch (lbs /in²) to kilonewtons per square metre (kN/m²), multiply by 6.895
7. To convert inch pounds (in-lbs.) to newton-metres (N-m), multiply by 0.113

An example of the imperial and their metric equivalents for our 3 5/8", 14 ga. stud is shown in the table below.

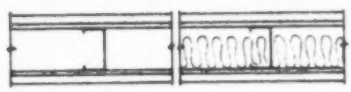
Physical and structural properties — imperial-metric (metric shown in red)

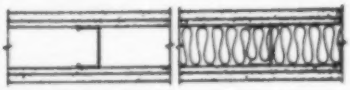
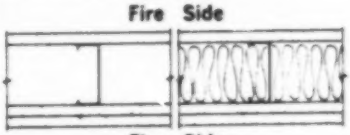
								Axis Major Axis			Axis Minor Axis			
3 1/4							92 s	1.113 18.24	614 10 062	1 580 4 613	16.7 5 951			

WALLS AND INTERIOR PARTITIONS, WOOD-FRAMED

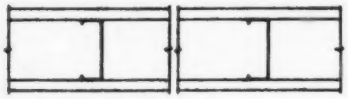
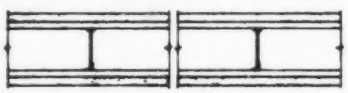
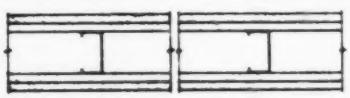
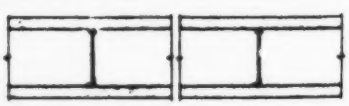
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
1 R	60 to 64	WP 3010	**Construction Type: Gypsum Wallboard, Mineral Fiber, Wood Studs** Base layer 5/8" type X gypsum wallboard or veneer base applied at right angles with 1" type S drywall screws 12" o.c. to resilient channels 24" o.c. attached at right angles to one side of 2 x 4 wood studs 16" o.c. with 1" type S drywall screws. Face layer 5/8" type X gypsum wallboard or veneer base applied on same side parallel with studs and spot laminated with 3/4" daubs of adhesive 12" o.c. each way. Opposite side base layer 5/8" type X gypsum wallboard or veneer base applied parallel to studs with 5d coated nails 1 5/8" long, 0.086" shank, 15/64" heads, 32" o.c. Center layer 1/2" type X gypsum wallboard or veneer base applied parallel to studs with 8d coated nails 2 3/8" long, 0.113" shank, 9/32" heads, 12" o.c. Face layer 3/8" regular gypsum wallboard applied parallel with studs and spot laminated to center layer with 3/4" daubs of adhesive 12" o.c. each way. Staple 2" glass fiber 0.90 pcf to three layer side in stud space. Stagger joints 16" o.c. each layer and side. (LB)	Fire Side  Thickness: 6 7/8" Approx. Weight: 12 psf Fire Test: UL R3660-2 Design U313, 12-3-68	Sound Test: RAL TL 69-117, 12-16-68
1 R	55 to 59	WP 3110	**Construction Type: Gypsum Wallboard, Mineral Fiber Wood Studs** Base layer 5/8" type X gypsum wallboard or veneer base applied at right angles with 1" type S drywall screws 12" o.c. to resilient channels 24" o.c. attached at right angles to one side of 2 x 4 wood studs 16" o.c. with 1" type S drywall screws. Face layer 5/8" type X gypsum wallboard or veneer base applied on same side parallel with studs and spot laminated with 3/4" daubs at adhesive 12" o.c. each way. Opposite side base layer 5/8" type X gypsum wallboard or veneer base applied parallel to studs with 5d coated nails 1 5/8" long, 0.086" shank, 15/64" heads, 32" o.c. Center layer 1/2" type X gypsum wallboard or veneer base applied parallel to studs with 8d coated nails 2 3/8" long, 0.113" shank, 9/32" heads, 12" o.c. Face layer 1/4" regular gypsum wallboard applied parallel with studs and spot laminated to center layer with 3/4" daubs of adhesive 12" o.c. each way. Staple 2" glass fiber 0.90 pcf to three layer side in stud space. Stagger joints 16" o.c. each layer and side. (LB)	Fire Side  Thickness: 6 3/4" Approx. Weight: 12 psf Fire Test: UL R3660-2 Design U313, 12-3-68	Sound Test: RAL TL 68-286, 6-20-68
	50 to 54	WP 3230	**Construction Type: Gypsum Wallboard, Mineral Fiber Wood Studs** One layer 5/8" type X gypsum wallboard or veneer base applied parallel to resilient channels 24" o.c. with 1" type S drywall screws in edges 6" o.c. and center row 12" o.c. End joints back-blocked with resilient channels. Resilient channels attached at right angles to 2 x 4 wood studs 16" o.c. with 6d coated nails. 1 7/8" long, 0.086" shank, 1/4" heads, 1/2" x 3" gypsum wallboard filler strip attached to plate at floor line with 6d nails as described above 16" o.c. 1 1/2" glass fiber 0.8 pcf attached to studs in stud space with 1/2" long staples. On opposite side one layer 5/8" type X gypsum wallboard or veneer base applied at right angles to studs with 6d nails as described above 8" o.c. Stagger end joints 48" o.c. each side. Sound tested with 3 1/2" glass fiber insulation. (LB)	Fire Side  Thickness: 5 1/8" Approx. Weight: 7 psf Fire Test: OSU T-3127, 10-4-65	Sound Test: RAL TL 77-138, 5-5-77

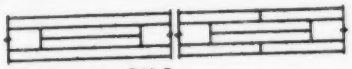
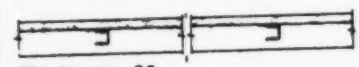
WALLS AND INTERIOR PARTITIONS, NONCOMBUSTIBLE

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
1 HR	55 to 59	WP 1015	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ¼" gypsum wallboard applied parallel to each side of 2½" metal studs 24" o.c. with 7/8" type S drywall screws 12" o.c. Face layer 3/8" type X gypsum wallboard or veneer base applied on each side parallel to studs with 1 5/16" type S drywall screws 12" o.c. Stagger joints 24" o.c. each layer and side. Sound tested using 1½" mineral fiber in stud space. (NLB)	 Thickness: 4¼" Limiting Height: 13'10" Approx. Weight: 8 psf Fire Test: See WP 1051 Sound Test: CK 684-14, 8-13-68	
	50 to 54	WP 1016 (g, k, x)	**Construction Type: Gypsum Wallboard, Metal Studs.** Base layer ¼" proprietary gypsum wallboard applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S, drywall screws 12" o.c. Face layer 5/8" type X gypsum wallboard or veneer base applied on each side parallel to studs with 1 3/8" long type S drywall screws 24" o.c. to studs and 12" o.c. to top and bottom runners. Stagger joints 24" o.c. each layer and side. Sound tested using 2" glass fiber friction fit in stud space. (NLB)	 Thickness: 4¼" Limiting Height: 13'10" Approx. Weight: 8 psf Fire Test: See WP 1050 Sound Test: G & H BW-18FT, 8-9-66	
		WP 1021	**Construction Type: Gypsum Wallboard, Metal Studs** One layer ½" type X gypsum wallboard applied parallel to one side of 2½" metal studs 24" o.c. with 1" type S drywall screws 8" o.c. to vertical edges and 3/8" adhesive beads to intermediate studs. Opposite side base layer ½" type X gypsum wallboard applied parallel to studs with 1" type S drywall screws 8" o.c. to vertical edges and 12" o.c.to intermediate studs. Face layer ½" type X gypsum wallboard applied parallel to studs with 1 5/8" type S drywall screws 8" o.c. to vertical edges and with adhesive beads over joints at intermediate studs. Stagger joints 24" o.c. each layer and face. Face layer may be predecorated. Sound tested using 3" glass fiber friction fit in stud space and all layers screw attached without adhesive. (NLB)	Fire Side Fire Side Thickness: 4" Limiting Height: 13'5" Approx. Weight: 7 psf Fire Test: FM WP 66, 12-8-66 Sound Test: Est. based on NGC 2253, 1-10-67	
		WP 1050 (g, k, x)	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ¼" proprietary gypsum wallboard applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 12" o.c. Face layer ½" type X gypsum wallboard, veneer base or vinyl faced wallboard applied on each side parallel to studs with 1 3/8" type S drywall screws in top and bottom runners 8" o.c. Apply ¾" beads of laminating compound 12" o.c. to full field of face layers. Stagger joints 24" o.c. each layer and side. Sound tested using 2" glass fiber friction fit in stud space. (NLB)	 Thickness: 4" Limiting Height: 13'10" Approx. Weight: 7 psf Fire Test: UL R2717-53, 54 Design U410, 9-4-68 ULC Design W400 Sound Test: G & H BW-17FT, 8-8-66	
		WP 1051	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ¼" gypsum wallboard applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 12" o.c. Face layer ½" type X gypsum wallboard or veneer base applied to each side parallel to studs with ¼" beads of laminating compound 2" o.c. to full field of face layers and with 1⅝" type S drywall screws in top and bottom runners 8" o.c. Stagger joints 24" o.c. each layer and side. Sound tested using 2" glass fiber friction fit in stud space and face layers screw attached without adhesive. (NLB)	 Thickness: 4" Limiting Height: 13'10" Approx. Weight: 7 psf Fire Test: FM WP 152-1, 1-22-69 Sound Test: NGC 2318, 8-19-68	

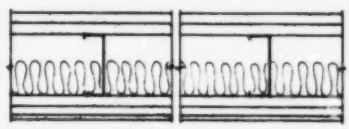
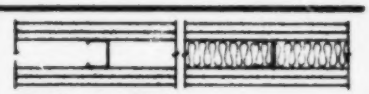
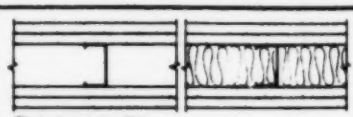
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
1 HR	50 to 54	WP 1053	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ⅜" square edged regular gypsum wallboard or backing board applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 12" o.c. in each stud and top & bottom track. Face layer ½" type X gypsum wallboard, or veneer base or predecorated gypsum wallboard applied on each side parallel to studs with 1⅜" type S drywall screws 8" o.c. to top and bottom runners only. Laminating compound in ¾" wide continuous beads 12" o.c. used between base and face layers. Stagger joints 24" each layer and side. Sound tested using 3½" glass fiber friction fit in stud space. (NLB).	 Thickness: 4¼" Limiting Height: 13'10" Approx. Weight: 7 psf Fire Test: ULC 74T184, Design W402, 4-10-75 Sound Test: CK 8104.02, 2-3-81	
	45 to 49	WP 1070	**Construction Type: Gypsum Wallboard, Mineral Fiber, Metal Studs** One layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 8" o.c. to edges and 12" o.c. to intermediate studs. 2" mineral fiber 2.5 pcf friction fit in stud space. Also fire tested with 1½" mineral fiber 3.0 pcf stapled to board in stud spaces. Stagger joints 24" o.c. each side. (NLB)	 Thickness: 3½" Limiting Height: 13'5" Approx. Weight: 5 psf Fire Test: FM WP 51-1, 9-22-66 Sound Test: RAL TL 69-42, 10-17-68	
		WP 1076 (d, w)	**Construction Type: Gypsum Wallboard, Metal Studs** One layer ⅝" proprietary type X gypsum wallboard or veneer base applied parallel to each side of 2½" metal studs 24" o.c. with 1¼" type S drywall screws 8" o.c. around perimeter of assembly and 12" o.c. at board edges. Wallboard fastened to intermediate studs with continuous ¼" beads of adhesive or 1¼" type S drywall screws 12" o.c. 2¾" glass fiber 0.65 pcf friction fit in stud space. Stagger joints 24" o.c. each side. (NLB)	 Thickness: 3¾" Limiting Height: 13'5" Approx. Weight: 6psf Fire Test: ULC 78T55, Design W409, 1-9-79 Sound Test: DRC 70-2-2, 1-6-70	
		WP 1080	**Construction Type: Gypsum Wallboard, Metal Studs** One layer ⅝" type X gypsum wallboard or veneer base applied parallel to each side of 3⅝" metal studs 24" o.c. with 1" type S drywall screws 8" o.c. to edges and vertical joints and 12" o.c. to intermediate studs. Face layer ⅝" type X gypsum wallboard or veneer base applied on one side parallel to studs with 1⅝" type S drywall screws 8" o.c. to edges and sides and 12" o.c. to intermediate studs. Apply ½" beads of laminating compound 2" o.c. to full field of face layer. Stagger joints 24" o.c. each layer and side. Sound tested using 3½" glass fiber in stud space. (NLB)	Fire Side  Fire Side Thickness: 5½" Limiting Height: 17'3" Approx. Weight: 8 psf Fire Test: OSU T-3240, 10-1-65 Sound Test: RAL TL 77-12, 10-8-76	
		WP 1090	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ¼" gypsum wallboard applied parallel to each side of 1⅝" metal studs 24" o.c. with 1" type S drywall screws 24" o.c. to edges and 36" o.c. to intermediate studs. Face layer ½" type X gypsum wallboard or veneer base applied on each side parallel to studs with 1⅝" type S drywall screws 12" o.c. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 3⅛" Limiting Height: 10'10" Approx. Weight: 7 psf Fire Test: UC, 12-28-65 Sound Test: ACI 7-1152019 c, 12-29-65	
		WP 1110	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ½" regular gypsum wallboard or veneer base applied parallel to each side of 1⅝" metal studs 24" o.c. with 1" type S drywall screws 12" o.c. Face layer ½" regular gypsum wallboard or veneer base applied on each side parallel to studs with 1⅝" type S drywall screws 12" o.c. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 3⅝" Limiting Height: 12'4" Approx. Weight: 9 psf Fire Test: UC, 9-21-84 Sound Test: KG 374, 6-24-86	

WALLS AND INTERIOR PARTITIONS, NONCOMBUSTIBLE

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
1 HR	40 to 44	WP 1200	**Construction Type: Gypsum Wallboard, Metal Studs** One layer ⅝" type X gypsum wallboard or veneer base applied at right angles or parallel to each side of 3⅝" metal studs 24" o.c. with 1" type S drywall screws 8" o.c. to vertical edges and top and bottom runners and 12" o.c. to intermediate studs. Stagger all vertical and horizontal joints 24" o.c. each side. (NLB)	 Thickness: 4⅞" Limiting Height: 17'3" Approx. Weight: 6 psf Fire Test: FM WP-45, 6-19-68 OSU T-1770, 4/61 Sound Test: NGC 2385, 7-28-70	
		WP 1230	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ⅝" regular gypsum wallboard or veneer base applied parallel to each side of 1⅝" metal studs 24" o.c. with 1" type S drywall screws 27" o.c. to edges and 54" o.c. to intermediate studs. Face layer ½" regular gypsum wallboard or veneer base attached on each side parallel to studs with 1⅝" type S drywall screws 12" o.c. to perimeter and 24" o.c. to intermediate studs. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 3⅛" Limiting Height: 12'0" Approx. Weight: 8 psf Fire Test: UC, 11-17-64 Sound Test: KG 141, 8-14-64	
		WP 1240	**Construction Type: Gypsum Veneer Base, Veneer Plaster, Metal Studs** One layer ½" type X gypsum veneer base applied parallel or at right angles to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 8" o.c. to edges or ends and 12" o.c. to intermediate studs. Omit screws in top and bottom runners. Stagger joints 24" o.c. each side. 1/16" gypsum veneer plaster applied over both sides. Sound tested with 3" glass fiber in stud space and with studs 16" o.c. (NLB)	 Thickness: 3⅝" Limiting Height: 14'8" Approx. Weight: 5 psf Fire Test: UC, 8-5-63, UC, 11-1-63; UC, 5-31-66 Sound Test: G & H NG-269FT, 12-20-65	
		WP 1260	**Construction Type: Gypsum Lath, Gypsum Plaster Metal Studs** ½" 1:2 gypsum-sand plaster applied over face of ⅜" plain gypsum lath fastened at right angles to each side of 2½" open web metal studs 16" o.c. with 12 gage galvanized wire clips. 16 gage furring channel stiffener installed horizontally at mid-height through web of studs and wire tied. Stagger end joints each lath on each side with end joint clips at lath corners. (NLB)	 Thickness: 4¼" Limiting Height: 11'2" Approx. Weight: 14 psf Fire Test: FM WP-65-1, 1-10-67 Sound Test: NGC 3042, 2-20-69	
		WP 1290	**Construction Type: Gypsum Lath, Gypsum Plaster, Metal Studs** ½" 1:2 gypsum-sand plaster applied over each face of ½" plain gypsum lath attached with 12 gage wire clips at right angles to each side of 2½" metal screw type studs spaced 24" o.c. End joint clips at lath corners. (NLB)	 Thickness: 4½" Limiting Height: 9'2" Approx. Weight: 15 psf Fire Test: FM WP-53, 11-29-66 Sound Test: NGC 2061, 10-24-66	
	35 to 39	WP 1300	**Construction Type: Gypsum Plaster, Metal Studs, Metal Lath** ⅝" 1:2 gypsum-sand plaster applied over 3.4 lb. metal lath attached with 24 gage galvanized steel clips 6" o.c. to each side of 3¼" open web metal studs spaced 16" o.c. (NLB)	 Thickness: 4¾" Limiting Height: 13'6" Approx. Weight: 13 psf Fire Test: OSU T-4228, 11-11-67 Sound Test: NGC 3039, 1-27-69	

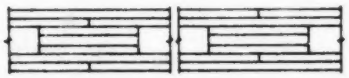
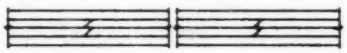
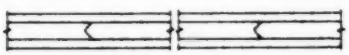
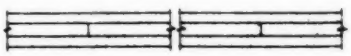
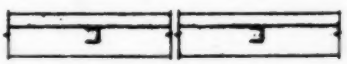
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA	
				Fire	Sound
1 R	35 to 39	WP 1310	**Construction Type: Solid Gypsum Wallboard** One layer ½" regular gypsum wallboard or veneer base laminated over the entire contact surface with laminating compound to each side of 1" tongue and groove gypsum coreboard erected vertically. Stagger joints 8" minimum each side. (NLB)	 Thickness: 2" Limiting Height: 11'0" Approx. Weight: 8 psf Fire Test: UC, 4-4-61 Sound Test: NGC 2359, 11-18-69	
		WP 1330	**Construction Type: Gypsum Wallboard, Semi-Solid Gypsum Studs** One layer ⅝" type X gypsum wallboard or veneer base applied parallel to each side of 6" wide gypsum studs 24" o.c. made of 2 or 3 layers of ½" or ⅝" laminated gypsum panels. Attach wallboard to gypsum studs with 1" type G drywall screws 20" o.c. and with laminating compound. Fire tested with 1" thick gypsum studs. Sound tested using ⅝" thick gypsum studs. (NLB)	 Thickness: 2½" Limiting Height: 12'0" Approx. Weight: 8 psf Fire Test: UL R2717-19, 21 Design U510, 6-3-57 ULC Design, W502 Sound Test: G & H BW-8 FT, 8-1-62	
		WP 1340	**Construction Type: Gypsum Wallboard, Metal Studs** One layer ⅝" type X gypsum wallboard or veneer base applied parallel to each side of 1⅝" metal studs 24" o.c. with 1" type S drywall screws 8" o.c. to edges and 12" o.c. to intermediate studs. Stagger joints 24" o.c. each side. (NLB)	 Thickness: 2⅞" Limiting Height: 10'0" Approx. Weight: 6 psf Fire Test: OSU T-3296, 10-1-65 Sound Test: RAL TL 64-244, 5-8-64	
		WP 1370	**Construction Type: Gypsum Plaster, Gypsum Lath, Metal Studs** ½" 1:2 gypsum-sand plaster applied over each face of ⅜" type X gypsum lath attached at right angles to each side of 2½" metal studs 24" o.c. with two 1" type S drywall screws and two butt joint clips per lath at lath ends. (NLB)	 Thickness: 4¼" Limiting Height: 11'6" Approx. Weight: 14 psf Fire Test: UC, 12-21-65 Sound Test: RAL TL 63-268, 6-4-63	
		WP 1380	**Construction Type: Gypsum Plaster, Metal Lath, Solid Metal Channel** 2" solid 1:1-1:2 gypsum-sand plaster applied over 2.5 lb. metal lath wire tied 6" o.c. to ¾" cold rolled channel studs 16" o.c. embedded in plaster. (NLB)	 Thickness: 2" Limiting Height: 12'6" Approx. Weight: 18 psf Fire Test: OSU T-129, 3-16-48 Sound Test: BMS 144/523, 2-25-55 & NBS Monograph 77, 11-30-64	
		WP 1390	**Construction Type: Gypsum Plaster, Solid Metal Lath** 2" 1:2 gypsum-sand plaster applied over each side of ⅜" rib metal lath to form 2" solid studless wall. (NLB)	 Thickness: 2" Limiting Height: 10'0" Approx. Weight: 18 psf Fire Test: OSU T-162, 4-28-51 Sound Test: BMS 144/527, 2-25-55 &NBS Monograph 77, 11-30-64	

WALLS AND INTERIOR PARTITIONS, NONCOMBUSTIBLE

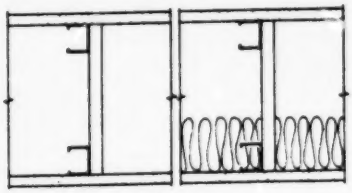
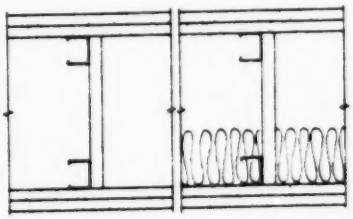
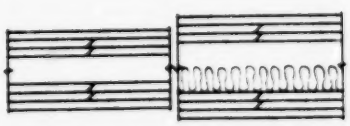
Fire ating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire / Sound
1 HR	35 to 39	WP 1400	**Construction Type: Gypsum Plaster, Metal Lath, Metal Studs** ⅝" 1:2-1:3 gypsum-sand plaster applied over 3.4 lb. metal lath wire tied 6" o.c. to each side of 1⅝" open or punched web metal studs 16" o.c. (NLB)	 Thickness: 3⅛" Limiting Height: 8'0" Approx. Weight: 18 psf Fire Test: OSU T-1511, 9-23-60 Sound Test: RAL TL 61-2, 9-8-60
	55 to 59	WP 1505 (d, w, x)	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ½" type X gypsum wallboard applied at right angles to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 12" o.c. Face layer ⅝" proprietary type X gypsum wallboard applied parallel to studs with vertical joints between studs and fastened to base layer only with 1½" type G drywall screws 12" o.c. Use of ⅜" to ½" dia. adhesive beads around the perimeter of face board, 2" from each edge and end, and in the form of an X joining the corners of the perimeter beads, is optional. Stagger joints 24" o.c. each layer and side. Sound tested with 2½" glass fiber in stud space. (NLB)	 Thickness: 4¾" Limiting Height: 15'10" Approx. Weight: 10 psf Fire Test: ULC 75T208, Design W404, 11-20-75 Sound Test: DRC 70-18-2, 2-16-70
		WP 1510	**Construction Type: Gypsum Wallboard, Mineral Fiber, Metal Studs** Base layer ⅝" type X gypsum wallboard or veneer base applied parallel to each side of 3⅝" metal studs 24" o.c. with 1" type S drywall screws 32" o.c. Staple 2" glass fiber 0.9 pcf to one side in stud space. Face layer ⅝" type X gypsum wallboard or veneer base applied parallel to one side of studs with 1⅝" type S drywall screws 12" o.c. to edges and 24" o.c. to intermediate studs. On opposite side second layer ½" type X gypsum wallboard or veneer base applied parallel to studs with 1⅝" type S drywall screws 12" o.c. Third face layer ¼" or ⅜" regular gypsum wallboard laminated parallel to studs with ¾" daubs of adhesive spaced 12" o.c. each way. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 6¼" Limiting Height: 19'5" Approx. Weight: 11 psf Fire Test: UL R3660-1 Design U403, 8-21-68 Sound Test: RAL TL 69-116, 12-16-68
2 HR		WP 1530	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 1⅝" metal studs 24" o.c. with 1" type S drywall screws 12" o.c. Face layer ½" type X gypsum wallboard or veneer base applied on each side parallel to studs with 1⅝" type S drywall screws 12" o.c. Stagger joints 24" o.c. each layer and side. Sound tested using 1½" mineral fiber in stud space. (NLB)	 Thickness: 3⅝" Limiting Height: 12'4" Approx. Weight: 9 psf Fire Test: UC, 12-7-64 Sound Test: ACI 1131 a, 7-14-64
	50 to 54	WP 1545	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 24" o.c. Face layer ½" type X gypsum wallboard or veneer base on each side applied parallel to studs with 1⅝" type S drywall screws 12" o.c. Stagger joints 24" o.c. each layer and side. Sound tested using 1½" mineral fiber in stud space. (NLB)	 Thickness: 4½" Limiting Height: 15'10" Approx. Weight: 9 psf Fire Test: UC, 9-7-64 Sound Test: CK 654-40, 9-7-65
		WP 1548	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ⅝" type X gypsum wallboard or veneer base applied at right angles to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 24" o.c. Screws spaced ½" from vertical end joints and ¾" from horizontal edge joints. Face layer ⅝" type X gypsum wallboard or veneer base applied at right angles to each side with 1⅝" type S drywall screws 12" o.c. Screws spaced ½" from vertical end joints and 1" from horizontal edge joints. Stagger joints 24" each layer and side. Sound tested with 2½" glass fiber in stud space. (NLB)	 Thickness: 5" Limiting Height: 19'5" Approx. Weight: 12 psf Fire Test: WHI, 495-0236, 1-30-80 Sound Test: WHI, 218-1, 8-11-80

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
	50 to 54	WP 1560	**Construction Type: Gypsum Veneer Base, Veneer Plaster, Metal Studs** Base layer ½" type X gypsum veneer base applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 24" o.c. Face layer ½" type X gypsum veneer base applied on each side parallel to studs with 1⅝" type S drywall screws 12" o.c. No screws in runners. Apply 3/32" gypsum-veneer plaster over each face. Stagger joints 24" o.c. each layer and side. Sound tested using 1" mineral fiber in stud space. (NLB)	 Thickness: 4¾" Limiting Height: 15'10" Approx. Weight: 10 psf Fire Test: UL R5085-7 Design U303, 12-1-66 Sound Test: CR 654-66, 12-29-65	
	45 to 49	WP 1615	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 24" o.c. Face layer ½" type X gypsum wallboard or veneer base applied parallel to each side of studs with 1⅝" type S drywall screws 12" o.c. (NLB)	 Thickness: 4½" Limiting Height: 15'10" Approx. Weight: 9 psf Fire Test: UC, 9-7-64 Sound Test: NGC 2250, 1-3-68	
		WP 1630	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 2½" metal studs 24" o.c. with 1" type S drywall screws 12" o.c. to perimeter and 36" o.c. to intermediate studs. Face layer ½" type X gypsum wallboard or veneer base on each side applied parallel to studs with drywall laminating adhesive in 4" wide strips 2" from board edges and 4" off board centerline and with 1¾" type S drywall screws 12" o.c. to perimeter and 16" o.c. to intermediate studs. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 4½" Limiting Height: 15'10" Approx. Weight: 9 psf Fire Test: OSU T-3218, 9-17-65 Sound Test: NGC 2111, 2-6-67	
1 2 IR		WP 1711	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ⅝" type X gypsum wallboard or veneer base applied parallel to each side of 3⅝" metal studs spaced 24" o.c. with 1" type S drywall screws 8" o.c. to edges and 12" o.c. to intermediate studs. Face layer ⅝" plain or predecorated type X gypsum wallboard or veneer base applied parallel to studs over base layers with laminating compound combed over entire surface. Metal base and top retainer channels. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 6⅛" Limiting Height: 19'5" Approx. Weight: 10 psf Fire Test: UL R1319-31, 32 Design U411, 6-2-60 Sound Test: RAL TL 61-213, 7-6-61	
	40 to 44	WP 1714	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ⅝" type X gypsum wallboard or veneer base applied parallel with 1" type S-12 drywall screws 12" o.c. to 18 gage steel studs 2½" wide with 1⅜" flange. Studs 16" o.c. braced laterally each side with ¾" cold rolled channel at ⅓ points screw attached with ½" type S-12 drywall screws. Studs welded both sides to floor and ceiling track. Face layer ⅝" type X gypsum wallboard or veneer base on each side applied parallel to studs with 1⅝" type S-12 drywall screws 12" o.c. Stagger joints 16" o.c. each layer and side. **Tested at 100 percent of design load.** (LB)	 Thickness: 5" Limiting Height: subject to design Approx. Weight: 10 psf Fire Test: FM WP 199-2, 1-25-71	
		WP 1720	**Construction Type: Gypsum Plaster, Gypsum Lath, Metal Studs** ¾" 1:2 gypsum-perlite plaster applied over ⅜" perforated gypsum lath attached at right angles to each side of 2½" open web metal studs spaced 16" o.c. with 12 gage wire clips. End joint clips at lath corners. (NLB)	 Thickness: 4¾" Limiting Height: 11'2" Approx. Weight: 13 psf Fire Test: OSU T-1813, 5-29-61	

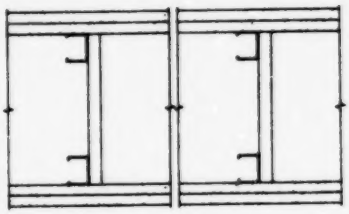
WALLS AND INTERIOR PARTITIONS, NONCOMBUSTIBLE

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire / Sound
2 HR	40 to 44	WP 1725	**Construction Type: Gypsum Plaster, Metal Lath, Metal Studs** ¾" 1:1, 1:1 fibered gypsum sand plaster applied over 3.4 lb. metal lath wire tied at right angles to each side of 2½" open web metal studs 16" o.c. (NLB)	 Thickness: 4¼" Limiting Height: 11'2" Approx. Weight: 16 psf Fire Test: UL R4024-9, 10, 1-5-67
	35 to 39	WP 1830	**Construction Type: Semi-Solid Gypsum Wallboard** Base layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 1⅝" x 6" type X gypsum board studs 24" o.c. with laminating compound combed over entire surface of gypsum studs and 2" type G drywall screws at 24" o.c. to studs. Face layer ½" type X gypsum wallboard or veneer base applied parallel to studs on each side with laminating compound combed over entire contact surface and 2" type G drywall screws spaced 24" o.c. into gypsum studs. Ends secured to top and bottom channels with 1½" type S drywall screws 24" o.c. Stagger joints 24" o.c. for each layer and side. (NLB)	 Thickness: 3⅝" Limiting Height: 14'0" Approx. Weight: 10 psf Fire Test: UC, 2-8-62
		WP 1840	**Construction Type: Solid Gypsum Wallboard** One layer ½" regular gypsum wallboard or veneer base applied with laminating compound over entire surface to each side of laminated, interlocking, gypsum coreboard 1" thick. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 2" Limiting Height: 11'0" Approx. Weight: 9 psf Fire Test: UL R3564 Design U508, 3-24-53 Sound Test: See WP 1310
		WP 1850	**Construction Type: Solid Gypsum Wallboard** One layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 1" tongue and groove gypsum coreboard with laminating compound combed over entire surface. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 2" Limiting Height: 11'0" Approx. Weight: 9 psf Fire Test: OSU T-1339, 4-8-60 Sound Test: See WP 1310
		WP 1860 (h)	**Construction Type: Solid Gypsum Wallboard** One layer ⅝" type X gypsum wallboard or veneer base applied vertically to each side of ¾" type X proprietary gypsum panel erected vertically. All layers attached to 25 gage ⅞" x 1½" angle at the perimeter with type S screws, 12" o.c. Facing layers attached with combed laminating compound on entire surface of gypsum panel and with 1⅝" type S screws 16" o.c. horizontally and vertically. Stagger joints 12" o.c. each layer and side. (NLB)	 Thickness: 2" Limiting Height: Refer to mfr. Approx. Weight: 8 psf Fire Test: WHI, 495-0288, 10-17-80 Sound Test: WHI-F14, 11-17-80
	30 to 34	WP 1930	**Construction Type: Gypsum Plaster, Solid Metal Channel, Metal Lath** 2½" solid 1:2-1:2 gypsum-perlite plaster applied over each side of 3.4 lb metal lath wire tied to one side of ¾" cold rolled channels 16" o.c. embedded in plaster. (NLB)	 Thickness: 2½" Limiting Height: 12'0" Approx. Weight: 12 psf Fire Test: UL R3453, 2-13-52

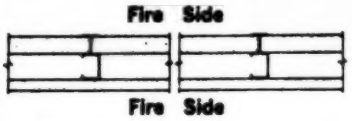
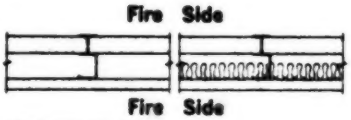
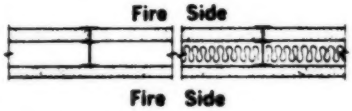
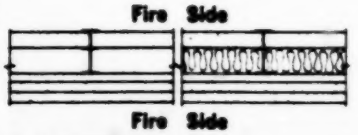
CHASE WALLS, NONCOMBUSTIBLE

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire / Sound
1 HR	50 to 54	WP 5015	**Construction Type: Gypsum Wallboard, Metal Studs** ⅝" type X gypsum wallboard or veneer base applied parallel to a double row of 1⅝" metal studs 24" o.c. and 6¼" apart with 1" type S drywall screws 8" o.c. at edges and top and bottom runners, 12" o.c. in field. Stagger joints 24" each side. 25 ga x 9½" long runner pieces located at ⅓ points used as cross braces and attached with two No. 8 x ½" self-drilling steel screws at each end. Optionally ⅝" gypsum board pieces 12" wide x 9½" long may be used as cross braces fastened to stud pairs with three 1" type S drywall screws at each end of brace. Sound tested using 3½" glass fiber stapled to one side in cavity. (NLB)	 Thickness: 10¾" Limiting Height: 16'0" Approx. Weight: 5½ psf Fire Test: UL R4024-13 Design U420, 11-17-76 Sound Test: RAL TL 76-155, 6-3-76
2 HR	55 to 59	WP 5105	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ⅝" type X gypsum wallboard or veneer base applied parallel to a double row of 1⅝" metal studs 24" o.c. and 6¼" apart with 1" type S drywall screws 8" o.c. at edges, 12" o.c. in field. 25 gage by 9½" long runner pieces located at ⅓ points used as cross braces and attached with two No. 8 x ½" self-drilling steel screws at each end. Optionally ⅝" gypsum board pieces 12" wide x 9½" long may be used as cross braces fastened to stud pairs with three 1" type S drywall screws at each end of brace. Face layers ⅝" type X gypsum wallboard or veneer base applied parallel to studs with 1⅝" type S drywall screws 8" o.c. at joints and top and bottom runners, 12" o.c. in field. Stagger joints each layer and side. Sound tested using 3½" glass fiber stapled to one side in cavity. (NLB)	 Thickness: 12" Limiting Height: 16'0" Approx. Weight: 10 psf Fire Test: UL R4024-13, 14 Design U420, 11-17-76 Sound Test: RAL TL 76-156, 6-7-76
		WP 5110	**Construction Type: Double Solid Gypsum Wallboard** One layer ½" gypsum wallboard or veneer base applied with ⅜" beads of laminating compound 2" o.c. to exterior side only of 1" gypsum coreboards placed on each side of 1" air space. Coreboard fastened with No. 6 x 1⅝" type S screws, three per board, into floor and ceiling runners. Sound tested with 3" air space and 1½" mineral fiber stapled on one side in cavity. (NLB)	 Thickness: 4" Limiting Height: 8'6" Approx. Weight: 12 psf Fire Test: UC, 4-25-61 Sound Test: ACI 109006c, 6-29-84
		WP 5111	**Construction Type: Double Solid Gypsum Wallboard** One layer ½" gypsum wallboard or veneer base applied with ⅜" beads of laminating compound 2" o.c. to exterior side only of 1" gypsum coreboards placed on each side of 1⅝" air space. Coreboard fastened with No. 6 x 1⅝" type screws, two per board, into ceiling runners. Sound tested with 3" air space and 1½" mineral fiber stapled on one side in cavity. (NLB)	 Thickness: 4⅝" Limiting Height: 8'6" Approx. Weight: 12 psf Fire Test: OSU T-1747, 6-15-61 Sound Test: ACI 109006c, 6-29-84

CHASE WALLS, NONCOMBUSTIBLE

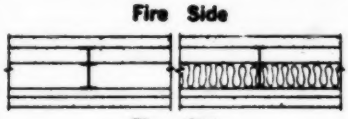
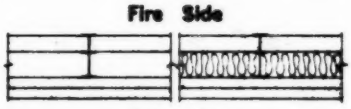
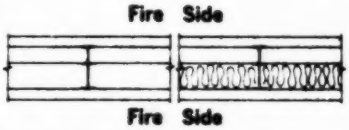
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
2 HR	50 to 54	WP 5130	**Construction Type: Gypsum Wallboard, Metal Studs** Base layer ⅝" type X gypsum wallboard or veneer base applied parallel to a double row of 1⅝" metal studs 24" o.c. and 6¼" apart with 1" type S drywall screws 8" o.c. at edges, 12" o.c. in field. 25 ga by 9½" long runner pieces located at ⅓ points used as cross braces and attached with two No. 8 x ½" self-drilling steel screws at each end. Optionally ⅝" gypsum board pieces 12" wide x 9½" long may be used as cross braces fastened to stud pairs with three 1" type S drywall screws at each end of brace. Face layers ⅝" type X gypsum wallboard or veneer base applied parallel to studs with 1⅝" type S drywall screws 8" o.c. at joints and top and bottom runners, 12" o.c. in field. Stagger joints each layer and side. (NLB)	 Thickness: 12" Limiting Height: 16'0" Approx. Weight: 10 psf Fire Test: UL R4024-13, 14 Design U420, 11-17-76 Sound Test: RAL TL 76-162, 6-11-76	
	45 to 49	WP 5210	**Construction Type: Double Solid Gypsum Wallboard** One layer ½" gypsum wallboard or veneer base applied with ⅜" beads of laminating compound 2" o.c. to exterior sides only of 1" gypsum coreboard placed on each side of 1" air space. Sound tested with 2½" air space. Coreboard fastened with No. 6 x 1⅝" type S screws, three per board, into floor and ceiling runners. (NLB)	 Thickness: 4" Limiting Height: 8'6" Approx. Weight: 12 psf Fire Test: UC, 4-25-61 Sound Test: KG 264, 9-13-65	
		WP 5211	**Construction Type: Double Solid Gypsum Wallboard** ½" gypsum wallboard or veneer base applied with ⅜" beads of laminating compound 2" o.c. to exterior sides only of 1" gypsum coreboards placed on each side of 1⅝" air space. Sound tested with 2½" air space. Coreboard fastened with No. 6 x 1⅝" type S screws, two per board, into ceiling runners. (NLB)	 Thickness: 4⅝" Limiting Height: 8'6" Approx. Weight: 12 psf Fire Test: OSU T-1747, 6-15-61 Sound Test: KG 264, 9-13-65	

SHAFT WALLS

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION†	SKETCH AND DESIGN DATA	
				Fire	Sound
1 HR	35 to 39	WP 7000 (n)	**Construction Type: Gypsum Wallboard, Metal C-T Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J runners with T section of 2½" proprietary C-T metal studs between proprietary gypsum panels. ⅝" type X gypsum wallboard applied vertically to the C side of C-T studs with 1" type S drywall screws 8" o.c. along edges and 12" o.c. at midwidth. (NLB)	 Thickness: 3⅛" Limiting Height: refer to mfr. Approx. Weight: 7 psf Fire Test: GET, 1-7-74	
		WP 7008 (t)	**Construction Type: Gypsum Wallboard, Metal C-H Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J runners with 2½" proprietary vented C-H studs between panels. One layer ⅝" proprietary type X gypsum wallboard or veneer base applied parallel to studs on side opposite proprietary gypsum panels with 1" type S drywall screws spaced 12" o.c. in studs and runners. STC estimate based on 1" mineral fiber in cavity. (NLB)	 Thickness: 3⅛" Limiting Height: refer to mfr. Approx. Weight: 8 psf Fire Test: GET, 4-3-75	
	40 to 44	WP 7009 (d,h,k,o, q,w)	**Construction Type: Gypsum Board, Slotted Metal I Studs** ¾" x 24" proprietary type X gypsum panels inserted between 2¼" floor and ceiling track and fitted to proprietary 2¼" slotted Metal I studs with tab-flange. Face layer ⅝" type X gypsum board applied at right angles to studs, with 1" type S drywall screws, 12" o.c. Sound tested with 1" glass fiber friction fit in stud space. (NLB)	 Thickness: 2⅞" Limiting Height: refer to mfr. Approx. Weight: 6 psf Fire Test: WHI 495-0187, 4-24-79 Sound Test: WHI F8, 5-3-79	
2 HR	50 to 54	WP 7055 (d,h,k,o, q,w)	**Construction Type: Gypsum Wallboard, Slotted Metal I Studs** ¾" x 24" type X proprietary gypsum panels inserted between 2¼" floor and ceiling runners and fitted into 2¼" slotted metal I studs with tab flange. On opposite side base layer ⅝" type X gypsum board applied parallel to studs with 1" type S drywall screws 24" o.c. Face layer ⅝" type X gypsum board or veneer base applied at right angles to studs with 1⅝" type S drywall screws. Sound tested with ⅝" thick base and face layers applied to resilient channels placed at right angles to studs 24" o.c. and fastened with 1" type S drywall screws. ½" x 3" gypsum board backing strips installed at floor line. 2½" glass fiber friction fit in stud space. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 8.5 psf Fire Test: WHI 495-105, 2-21-78 WHI 495-111, 3-7-78 Sound Test: WHI FI, 3-13-78	
		WP 7060 (p)	**Construction Type: Gypsum Wallboard, Metal I Studs** 1" x 24" type X proprietary gypsum panels inserted between 2½" floor and ceiling track with tab-flange section of 2½" metal I studs between proprietary gypsum panels. Resilient channels screw attached, top leg only at right angles to I studs 24" o.c. maximum with ⅜" type S screws. Two layers of ⅝" type X gypsum wallboard or veneer base over resilient channels with base layer applied parallel to resilient channels with 1" type S drywall screws 24" o.c. and face layer applied at right angles to base layer with 1⅝" type S drywall screws 12" o.c. Sound tested using 1½" glass fiber friction fit in stud space. (NLB)	 Thickness: 4⅛" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: UC ES-7408, 11-21-75 (Rev. 8-76) Sound Test: KAL 437382, 11-3-76	

†Where vertical metal sections are field installed, their center to center spacing shall not exceed panel dimensions described above, which are nominal.

SHAFT WALLS

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION†	SKETCH AND DESIGN DATA	
				Fire	Sound
2 HR	50 to 54	WP 7061 (p)	**Construction Type: Gypsum Wallboard, Metal I Studs** 1" x 24" type X proprietary gypsum panels inserted between 2½" floor and ceiling track with tab-flange section of 2½" metal I studs between proprietary gypsum panels. One layer of ⅝" type X gypsum wallboard or veneer base applied at right angles to flanges of I studs adjacent to proprietary gypsum panels with 1" type S drywall screws 12" o.c. Resilient channels spaced 24" o.c. horizontally, screw attached, top leg only, to opposite flanges of I studs with ⅜" type S screws. ⅝" type X gypsum wallboard or veneer base applied parallel to resilient furring channels with 1" type S drywall screws 12" o.c. Sound tested using 1½" glass fiber friction fit in stud space. (NLB)	 Fire Side Thickness: 4¼" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: UC ES-7407, 1-22-76 Sound Test: KAL 437363, 11-4-76	
	45 to 49	WP 7078 (p)	**Construction Type: Gypsum Wallboard, Metal I Studs** 1" x 24" type X proprietary gypsum panels inserted between 2½" floor and ceiling track with tab-flange section of 2½" metal I studs between proprietary gypsum panels. Two layers of ⅝" type X gypsum wallboard or veneer base applied to face of metal I studs. Base layer applied at right angles or parallel to studs with 1" type S drywall screws 24" o.c. and face layer applied at right angles to base layer with 1⅝" type S drywall screws 12" o.c. Sound tested using 2½" glass fiber friction fit in stud space. (NLB)	 Fire Side Thickness: 3¾" Limiting Height: refer to mfr. Approx. Weight: 8½ psf Fire Test: UC ES-7406, 11-21-75 Sound Test: NGC 2507, 7-21-75	
		WP 7077 (p)	**Construction Type: Gypsum Wallboard, Metal I Studs** 1" x 24" type X proprietary gypsum panels inserted between 2½" floor and ceiling track with tab-flange section of 2½" metal I studs between proprietary gypsum panels. One layer of ⅝" type X gypsum wallboard or veneer base applied at right angles to each side of metal I studs with 1" type S drywall screws 12" o.c. Sound tested using 1½" glass fiber friction fit in stud space. (NLB)	 Fire Side Thickness: 3¾" Limiting Height: refer to mfr. Approx. Weight: 8½ psf Fire Test: UC ES-7407, 1-22-76 Sound Test: NGC 2543, 5-18-76	
		WP 7078 (h,k,o,q)	**Construction Type: Gypsum Wallboard, Metal I Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling track with tab-flange section of 2½" metal I studs between proprietary gypsum panels. Two layers of ⅝" type X gypsum wallboard or veneer base applied to face of metal I studs. Base layer applied at right angles or parallel to studs with 1" type S drywall screws 24" o.c. and face layer applied at right angles to base layer with 1⅝" type S drywall screws 12" o.c. Sound tested using 2½" glass fiber friction fit in stud space. (NLB)	 Fire Side Thickness: 3¾" Limiting Height: refer to mfr. Approx. Weight: 8½ psf Fire Test: WHI 495-0091, 12-9-77 WHI 495-0095, 12-16-77 Sound Test: WHI T2, 3-13-78	
		WP 7088 (n)	**Construction Type: Semi Solid Gypsum Board, Metal Shaft Studs** Two layers ½" x 24" type X gypsum wallboard fitted to proprietary 2" metal studs retained at top by 2" J track and attached at floor to 2" angle runner with 1⅝" type S screws, 6" o.c. Two layers ⅝" type X gypsum wallboard applied parallel to studs on room side with base layer attached with 1¼" type S drywall screws 24" o.c. and face layer of gypsum wallboard or veneer base attached with 1⅞" type S drywall screws, 12" o.c. Stagger joints 24" o.c. each layer. (NLB)	 Fire Side Thickness: 3¼" Limiting Height: 15'8" Approx. Weight: 8½ psf Fire Test: OSU 5836, 3-12-76	

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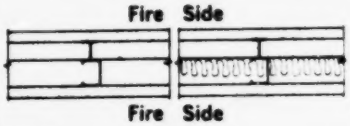
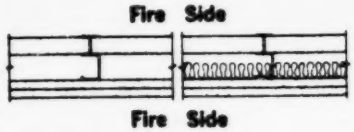
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION†	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
2 HR	45 to 49	WP 7088 (d,h,k,o, q,w)	**Construction Type: Gypsum Wallboard, Slotted Metal I Studs** ¾" x 24" proprietary type X gypsum panels inserted between 2¼" floor and ceiling track and fitted to 2¼" slotted metal I studs with tab-flange. Face layer ⅝" type X gypsum board or veneer base applied at right angles to studs on cavity side and parallel to studs on gypsum panel side with 1¼" type S drywall screws, 12" o.c. beginning 6" from bottom. No screws in top and bottom runners. Sound tested using 2½" glass fiber friction fit in stud space. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 8.0 psf Fire Test: WHI 495-0126, 4-26-78 WHI 495-0127, 4-28-78	Sound Test: WHI F3, 3-13-78
		WP 7089 (d,h,k,o, q,w)	**Construction Type: Gypsum Wallboard, Slotted Metal I Studs** ¾" x 24" proprietary type X gypsum panels inserted between 2¼" floor and ceiling track and fitted to 2¼" slotted metal I studs with tab-flange. Base layer ⅝" type X gypsum board applied at right angles to studs with 1" type S drywall screws, 24" o.c. Face layer ⅝" type X gypsum board or veneer base applied parallel to studs with 1⅝" type S drywall screws, 12" o.c. Sound tested using 2½" glass fiber friction fit in stud space. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 8.0 psf Fire Test: WHI 495-105, 2-21-78 WHI 495-111, 3-7-78	Sound Test: WHI F2, 3-13-78
		WP 7092 (n)	**Construction Type: Gypsum Wallboard, Metal C-T Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J runners with T section of 2½" proprietary C-T metal studs between proprietary gypsum panels. Two layers ½" type X gypsum wallboard applied to face of C-T metal studs. Base layer applied at right angles to studs with 1" type S drywall screws 24" o.c. and face layer applied at right angles to studs with 1⅝" type S drywall screws 8" o.c. Stagger joints 24" o.c. each layer. Sound tested using 1" thick glass fiber stapled in cavity. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: WHI, 3-23-77	
		WP 7093 (n)	**Construction Type: Gypsum Wallboard, Metal C-T Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J runners with T section of 2½" proprietary C-T metal studs between proprietary gypsum panels. One layer ½" type X gypsum wallboard applied at right angles to each side of C-T studs with 1" type S drywall screws 8" o.c. Stagger joints each side. Sound tested using 1" thick glass fiber stapled in cavity. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: See WP 7109	
		WP 7095 (t)	**Construction Type: Gypsum Wallboard, Metal C-H Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J runners with 2½" proprietary vented C-H studs between panels. Two layers ½" type X gypsum wallboard or veneer base applied parallel to studs on side opposite gypsum panels with 1" type S drywall screws 24" o.c. in the base layer and 1⅝" type S screws 12"o.c. in studs and runners for the face layer. Face layer joints offset 24" o.c. from base layer. Sound tested with 1" mineral fiber in cavity. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: GET, 4-2-75	Sound Test: BBN 750708, 7-16-75

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SHAFT WALLS

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION†	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
2 HR	40 to 44	WP 7104 (n)	**Construction Type: Gypsum Wallboard, Metal C-T Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J track with T section of 2½" proprietary C-T metal studs between proprietary gypsum panels. Two layers ½" type X gypsum wallboard applied to face of C-T studs. Base layer applied at right angles to studs with 1" type S drywall screws 24" o.c. and face layer applied at right angles to studs with 1⅝" type S drywall screws 8" o.c. Stagger joints 24" o.c. each layer. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: WHI, 3-23-77 Sound Test: WHI 0034-2, 4-15-77	
		WP 7109 (n)	**Construction Type: Gypsum Wallboard, Metal C-T Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J runners with T section of 2½" proprietary C-T metal studs between proprietary gypsum panels. One layer ½" type X gypsum wallboard applied at right angles to each side of C-T studs with 1" type S drywall screws 8" o.c. Stagger joints each side. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: WHI, 4-15-77 Sound Test: WHI 0034-1, 4-15-77	
	35 to 39	WP 7111	**Construction Type: Solid Gypsum Wallboard, Steel H Members** 2" x 24" laminated gypsum board panels installed vertically between floor and ceiling J runners, with H members between panels. H members formed from 2" x 1" 25 ga channels placed back to back and spot welded 24" o.c. Two layers of ½" regular gypsum wallboard or veneer base on unexposed side applied parallel to H members with ⅞" type S drywall screws staggered along flanges 12" o.c. inner layer and 1⅝" type S drywall screws staggered along flanges 12" o.c. outer layer. Vertical joints of layers offset 24". (NLB)	 Thickness: 3" Limiting Height: subject to design Approx. Weight: 12 psf Fire Test: OSU T-4481, 4-9-68 Sound Test: RAL TL 70-69, 11-7-69	
		WP 7117 (t)	**Construction Type: Gypsum Wallboard, Metal C-H Studs** 1" x 24" proprietary type X gypsum panels inserted between 2½" floor and ceiling J runners with 2½" proprietary vented C-H studs between panels. One layer ½" type X gypsum wallboard or veneer base applied parallel to each side of studs with 1" type S drywall screws 12" o.c. Joints offset 24" o.c. (NLB)	 Thickness: 3½" Limiting Height: refer to mfr. Approx. Weight: 9 psf Fire Test: GET, 6-23-75	
		WP 7125	**Construction Type: Gypsum Wallboard, Metal Studs** Four layers ⅝" type X gypsum wallboard or veneer base applied at right angles to one side of 1⅝" metal studs 24" o.c. Base layer attached to studs with 1" type S drywall screws 12" o.c. Second layer attached to studs with 1⅝" type S drywall screws using only two screws per board. Third layer attached with 2⅝" type S drywall screws similar to second layer. Steel strips 1½" wide vertically applied over third layer at stud lines and attached 12" o.c. to studs with 2⅝" type S drywall screws. Third layer also attached to top and bottom track with 2⅝" type S drywall screws placed midway between studs. Face layer attached to steel strips with 1" type S drywall screws 8" o.c. at each stud. Stagger joints of each layer. (NLB)	 Thickness: 4⅛" Limiting Height: subject to design Approx. Weight: 9½ psf Fire Test: GET, 4-13-70 Sound Test: KG 634, 4-1-70	

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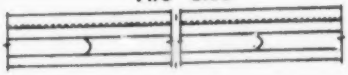
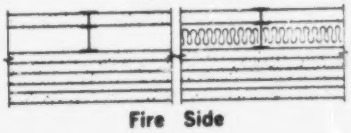
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION†	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
2 HR	30 to 34	WP 7210	**Construction Type: Solid Gypsum Wallboard** One layer ⅝" type X gypsum wallboard or veneer base applied vertically to each side of 1" gypsum board panels (solid or laminated) with laminating compound combed over entire contact surface. Panel supported by metal runners at top and bottom and horizontal bracing angles of No. 22 gage galvanized steel ¾" x 1¼" spaced 5'0" o.c. or less on shaft side. (NLB) *Limiting height shown is based on interior partition exposure conditions. Shaft wall exposure conditions may require reduction of limiting height.	Fire Side  Thickness: 2¼" Limiting Height: 11'0"* Approx. Weight: 9 psf Fire Test: UL R1319-58, 74 Design U505, 12-29-64	
3 HR	50 to 54	WP 7421 (d,h,k,o q,w)	**Construction Type: Gypsum Board, Slotted Metal I Studs** ¾" x 24" type X proprietary gypsum panels inserted between 2¼" floor and ceiling tracks and fitted to 2¼" slotted metal I studs with tab-flange. First layer ⅝" type X gypsum board applied at right angles to studs with 1" type S drywall screws, 24" o.c. Second layer ⅝" type X gypsum board applied parallel to studs with 1⅝" type S drywall screws, 42" o.c. starting 12" from bottom. Third layer ⅝" type X gypsum board applied parallel to studs with 2¼" type S drywall screws, 24" o.c. Resilient channels applied 24" o.c. at right angles to studs with 2¼" type S drywall screws. Fourth layer ⅝" type X gypsum board applied at right angles to resilient channels with 1" type S drywall screws, 12" o.c. Sound tested with 1" glass fiber friction fit in stud space and with ½" regular gypsum board applied parallel or perpendicular to studs on gypsum panel side with 1" type S drywall screws, 12" o.c. (NLB)	Fire Side Fire Side Thickness: 5¾" Limiting Height: refer to mfr. Approx. Weight: 15 psf Fire Test: WHI 495-0189, 4-27-79 WHI 495-0190, 4-30-79 Sound Test: WHI F10, 5-25-79	
	45 to 49	WP 7450 (d,h,k,o q,w)	**Construction Type: Gypsum Board, Slotted Metal I Studs** ¾" x 24" proprietary type X gypsum panels inserted between 2¼" floor and ceiling tracks and fitted to 2¼" slotted metal I studs with tab-flange. First layer ⅝" type X gypsum board applied at right angles to studs with 1" type S drywall screws 24" o.c. Second layer ⅝" type X gypsum board applied parallel to studs with 1⅝" type S drywall screws 42" o.c. starting 12" from bottom. Third layer ⅝" type X gypsum board applied parallel to studs with 2¼" type S drywall screws, 24" o.c. Resilient channels applied 24" o.c. at right angles to studs with 2¼" type S drywall screws. Fourth layer ⅝" type X gypsum board applied at right angles to resilient channels with 1" type S drywall screws, 12" o.c. Sound tested with 1" glass fiber friction fit in stud space. (NLB)	Fire Side  Fire Side Thickness: 5¼" Limiting Height: refer to mfr. Approx. Weight: 13 psf Fire Test: WHI 495-0189, 4-27-79 WHI 495-0190, 4-30-79 Sound Test: WHI F9, 5-23-79	
	40 to 44	WP 7510	**Construction Type: Semi-Solid Gypsum Wallboard** 2" x 24" laminated gypsum board panels installed vertically between floor and ceiling 20 gage J runners with 25 gage steel H members between panels. Panels attached at midpoint to 2½" leg of J runners with 2⅜" type S-12 drywall screws. H studs formed from 20 or 25 gage 2" x 1" channels placed back to back and spot welded 24" o.c. Base layer ⅝" gypsum wallboard or veneer base applied parallel to one side of panels, with 1" type S drywall screws 12" o.c. to H studs. Rigid furring channels horizontally attached 24" o.c. to H studs with 1" type S drywall screws. Face layer ⅝" gypsum wallboard or veneer base attached at right angles to furring channels with 1" type S drywall screws 12" o.c. Stagger joints 24" o.c. each layer and side. (NLB)	Fire Side Thickness: 4⅛" Limiting Height: subject to design Approx. Weight: 14 psf Fire Test: OSU T-4423, 3-21-88	

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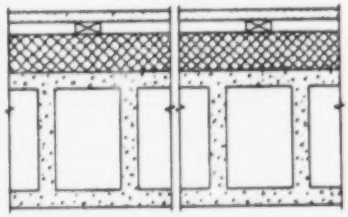
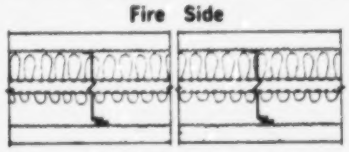
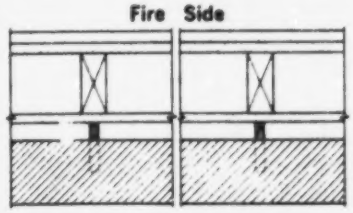
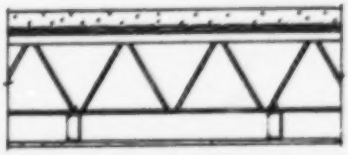
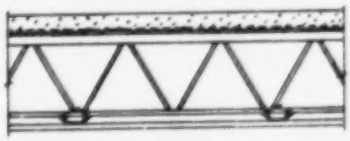
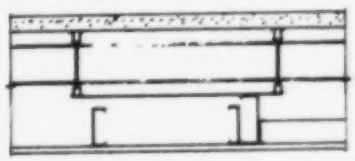
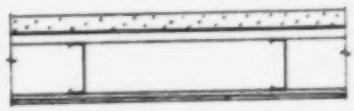
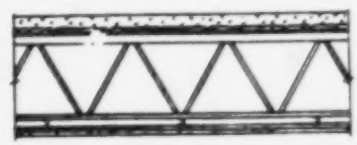
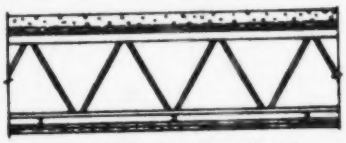
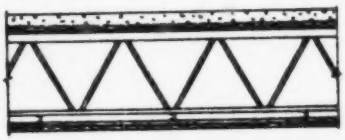
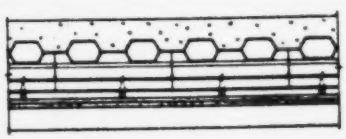
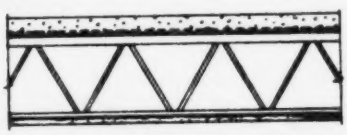
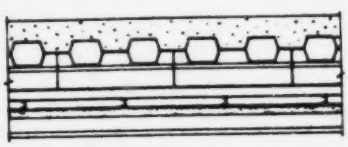
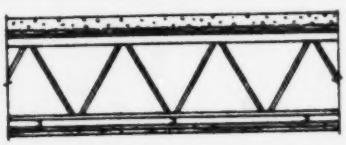
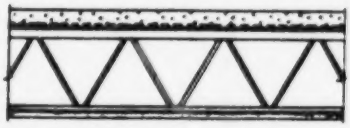
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA Fire / Sound
2 HR	50 to 54	WP 8201 (g)	**Construction Type: Lightweight Concrete Block, Foam Insulation, Wood Furring, Gypsum Wallboard** ⅝" type X gypsum wallboard applied vertically with joints taped and secured with 2" long 6d smooth bright nails 0.115" shank, 0.265" head, 8" o.c. to pressure treated 1" x 2" wood furring spaced 24" o.c. vertically and with horizontal members at floor and ceiling secured with 4" x 3/16" concrete fasteners spaced 24" o.c. over 2¼" proprietary aluminum foil faced glass reinforced isocyanurate foam insulation applied vertically with ¼" beads of construction grade adhesive applied to back of panels 16" o.c. (4 per board width), over nominal 8" x 8" x 16" x 1¼" shell lightweight 2 cell 55% solid concrete block with ⅜" type N mortar joints. **Wall loaded to 271 psi.** (LB)	**Fire Side**  Thickness: 11⅜" Approx. Weight: 37 psf Fire Test: OSU 6536, 3-19-79 Sound Test: Est.
		WP 8250 (t)	**Construction Type: Gypsum Wallboard, Steel Studs, Gypsum Sheathing, Metal Lath, Cement-Lime Stucco, Mineral Fiber** One layer ⅝" foil backed type X proprietary gypsum wallboard or veneer base applied parallel to 3⅝", 20 gage metal studs 16" o.c. with 1" type S-12 drywall screws 8" o.c. Friction fit mineral fiber 3" thick 2 pcf in stud cavity. Opposite side 3.4 lb. self-furring metal lath applied over ½" gypsum sheathing attached at right angles to studs. Metal lath attached through sheathing to studs with 1¼" type S-12 drywall screws 8" o.c. 1" portland cement-lime stucco face. (NLB)	**Fire Side** Thickness: 5¾" Approx. Weight: 20 psf Fire Test: OSU T-4851, 6-70 Sound Test: Est.
	45 to 49	WP 8310	**Construction Type: Steel Studs, Metal Lath, Gypsum Plaster, Mineral Fiber** Exterior face 1" portland cement-lime plaster applied over 3.4 lb. galvanized metal lath wire tied with 18 gage steel wire to 4" punched steel studs 16" o.c. with ¾" channels bridging at third points. Interior unexposed side 1" 1:2 gypsum-sand plaster applied over 3.4 lb. metal lath wire tied to vertically installed ¼" dia. pencil rods attached to studs with resilient clips. 2 mil polyethylene vapor barrier on interior side of stud cavity and 3" mineral fiber 3.86 pcf friction fit in stud space. (NLB)	**Fire Side**  Thickness: 6½" Fire Test: OSU T-4133, 1-17-68 Sound Test: Est.
		WP 8325	**Construction Type: Gypsum Wallboard, Steel Studs, Metal Lath, Perlite-Cement Lime Plaster** ⅝" type X gypsum wallboard or veneer base applied parallel to 3⅝", 20 gage metal studs 16" o.c. with 1" type S-12 drywall screws 12" o.c. Stud cavity filled with 3¼" 6:1:1 Perlite-Portland Cement Lime back plaster, spray applied. Opposite side 1½" x 17 ga galv woven wire self-furring paper backed lath attached to studs with ½" S-12 panhead screws 6" o.c. 1" 6:1:1 Perlite-Portland Cement Lime plaster face. (NLB) Achieved 4 hours when tested from cement side.	**Fire Side** **Fire Side** Thickness: 5¼" Approx. Weight: 14 psf Fire Test: OSU 5645, 5-7-75 Sound Test: Est.
	40 to 44	WP 8410	**Construction Type: Gypsum Wallboard, Wood Studs, Gypsum Sheathing, Clay Brick** Interior base layer ⅝" type X gypsum wallboard or veneer base applied parallel to or at right angles to 2 x 4 wood studs 16" o.c. with 6d coated nails, 1⅞" long, 0.0915" shank, ¼" heads, 8" o.c. Face layer ⅝" type X gypsum wallboard or veneer base applied parallel to or at right angles to studs with 8d coated nails, 2⅜" long, 0.113" shank, 9/32" heads, 8" o.c. Exterior base layer ½" gypsum sheathing applied at right angles to studs with galvanized roofing nails, 1¾" long, 0.125" shank, 7/16" heads 6" o.c. Face layer 2" x 4" x 8" clay brick with 1" air space between brick and exterior sheathing. No. 20 gage galvanized wire ties attached to each stud with 8d coated nails as described above, located at every 6th course of bricks. (LB)	**Fire Side**  Thickness: 10⅛" Fire Test: UL R1505-1, 2 Design U302, 4-22-65 ULC Design U302

FLOOR-CEILING ASSEMBLIES, NONCOMBUSTIBLE

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA
1 HR	50 to 54	FC 1105	**Construction Type: Gypsum Wallboard, Steel Joists, Concrete Slab** ½" type X gypsum wallboard or veneer base applied at right angles to 3⅝" steel studs spaced 24" o.c. with 1" type S drywall screws 12" o.c. Studs wire tied with double strand 18 gage wire 8'-0" o.c. to steel joists spaced 24" o.c. supporting ⅜" rib metal lath and 2½" concrete slab. (One hour restrained and unrestrained.)	 Approx. Ceiling Weight: 2 psf Fire Test: FM FC-134, 12-16-69 Sound Test: See FC 2030
	45 to 49	FC 1110	**Construction Type: Gypsum Wallboard, Steel Joists, Concrete Slab** ½" type X gypsum wallboard or veneer base applied at right angles to rigid furring channels 24" o.c. with 1" type S drywall screws 12" o.c. in field. Wallboard end joints located midway between continuous channels and attached to additional pieces of channel 54" long with screws 8" o.c. Furring channels wire-tied 24" o.c. to open web steel joists supporting ⅜" rib metal lath or 9/16" deep 28 gage corrugated steel and 2" concrete slab measured from top of flute. (Passed 90 minute fire test restrained and unrestrained.)	 Approx. Ceiling Weight: 2 psf Fire Test: UL R2717-30 Design G502, 6-12-64
		FC 1130	**Construction Type: Gypsum Wallboard, Steel Joists, Concrete Slab** ⅝" type gypsum wallboard or veneer base applied at right angles to 3⅝" or 6" steel studs placed horizontally and spaced 16" o.c. with 1" type S drywall screws 12" o.c. to form ceiling envelope without direct attachment to joists except at stud ends. At end joint locations a 54" long backing stud is attached to the continuous stud with six ⅜" long self tapping screws 10" o.c. Studs with a stud sleeve on one end inserted in runners around side walls suspended by ⅛" x 1" steel straps from open web steel bar joists 24" o.c. supporting 2" concrete slab laid over ⅜" rib metal lath. Maximum span for 3⅝" studs is 11'-10" at 16" o.c. and 12'-10" for 6" studs at 16" o.c.	 Approx. Ceiling Weight: 2 psf Fire Test: OSU T-3694, 11-5-66
		FC1145	**Construction Type: Gypsum Wallboard, Steel Joists, Concrete Slab** ½" type X gypsum wallboard or veneer base applied at right angles to resilient furring channels 24" o.c. with 1" type S drywall screws 12" o.c. set back 2" from edges. Wallboard end joints located midway between continuous channels and attached to additional pieces of channel 54" long with screws at 12" o.c. Furring channels applied at right angles to 6" x 1⅝" flanged 18 gage steel channel joists 24" o.c. with two ⅜" type S-12 screws supporting 25 gage corrugated metal deck and 2" (measured from top of flute) light weight concrete of 105 pcf density. (One hour unrestrained)	 Approx. Ceiling Weight: 2 psf Fire Test: FM FC 245-1, 1-27-77
		FC 1150	**Construction Type: Steel Joists, Concrete Slab, Gypsum Lath, Gypsum Plaster** ½" 1:2 gypsum-perlite plaster applied over ⅜" perforated gypsum lath clip attached to ¾" cold rolled channels 16" o.c. wire tied with 18 gage wire to open web steel joists 24" o.c. supporting ⅜" rib metal lath and 2" concrete slab.	 Approx. Ceiling Weight: 3 psf Fire Test: BMS 141/317, 8-23-54 IIC & Test: 26 (73 C & P) NGC 5089, 9-18-67

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA
3 HR	45 to 49	FC 3110	**Construction Type: Steel Joists, Concrete Slab, Gypsum Lath, Gypsum Plaster** ⅝" 1:2 gypsum-perlite plaster applied over ⅜" perforated gypsum lath clip attached providing continuous support across the lath and additionally supported with 14 gage diagonal wire reinforcing to ¾" cold rolled channel 12" o.c. wire tied with 18 gage wire to open web steel joists 24" o.c. supporting ⅜" rib metal lath and 2" concrete slab.	 Approx. Ceiling Weight: 5 psf Fire Test: NBS 313, 5-7-52
		FC 3120	**Construction Type: Steel Joists, Concrete Slab, Gypsum Lath, Gypsum Plaster** ½" 1:2 gypsum-perlite plaster applied over ⅜" perforated gypsum lath clip attached providing continuous support across the lath and additionally supported with 1" hexagonal mesh 20 gage galvanized wire fabric to ¾" cold rolled channels 16" o.c. wire tied with 18 gage wire to open web steel joists 24" o.c. supporting ⅜" rib metal lath and 2" concrete slab.	 Approx. Ceiling Weight: 4 psf Fire Test: NBS 312, 3-4-52
		FC 3130	**Construction Type: Concrete Slab, Cellular Steel Deck, Gypsum Lath, Gypsum Plaster** ½" 1:2 gypsum-perlite plaster applied over ⅜" perforated gypsum lath clip attached providing continuous support across the lath and additionally supported with 14 gage diagonal wire reinforcing to ¾" hot rolled channels 12" o.c. wire tied to 1½" cold rolled channels 24" o.c. suspended from the steel deck with No. 8 gage steel wire or 3/16" x 1" steel straps 24" o.c. 2½" concrete slab over 3" cellular rolled steel deck supported by steel beam. Back of lath 7¼" below deck and 2¾" below bottom of beam flange.	 Approx. Ceiling Weight: 3 psf Fire Test: NBS 337, 3-4-54
		FC 3140	**Construction Type: Steel Joists, Metal Lath, Gypsum Plaster** ⅝" 1:2-1:3 gypsum-vermiculite plaster or ⅞" neat-wood fiber gypsum plaster applied over 3.4 lb. metal lath wire tied with 18 gage wire 5" o.c. to open web steel joists 24" o.c. supporting ⅜" rib metal lath and 2½" concrete slab.	 Approx. Ceiling Weight: 4 psf Fire Test: BMS 92/43, 10-7-42
		FC 3150	**Construction Type: Concrete Slab, Cellular Steel Deck, Metal Lath, Gypsum Plaster** ⅝" thick mill-mixed gypsum-perlite plaster applied over 3.4 lb. metal lath wire tied to ¾" cold rolled channels 12" o.c. wire tied to 1½" cold rolled channels 48" o.c. suspended 16" with 8 gage steel wire 36" o.c. from 2" concrete slab over 3" cellular steel deck supported by steel beam. (Three hour restrained and unrestrained.)	 Approx. Ceiling Weight: 2½ psf Fire Test: UL R3574-6 Design A403, 7-25-57
4 HR	45 to 49	FC 4110	**Construction Type: Steel Joists, Concrete Slab, Gypsum Lath, Gypsum Plaster** 1" 1:2-1:3 gypsum-perlite plaster applied over ⅜" perforated gypsum lath clip attached providing continuous support across the lath and additionally supported with 1" hexagonal mesh 20 gage galvanized wire fabric to ¾" cold rolled channels 12" o.c. wire tied to open web steel joists 24" o.c. supporting ⅜" rib metal lath and 2" concrete slab.	 Approx. Ceiling Weight: 5½ psf Fire Test: NBS 311, 1-8-52

FLOOR-CEILING ASSEMBLIES, NONCOMBUSTIBLE

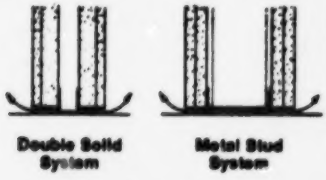
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA
4 HR	45 to 49	FC 4120	**Construction Type: Steel Joists, Concrete Slab, Metal Lath, Gypsum Plaster** ⅞" 1:2-1:3 gypsum-vermiculite plaster applied over ⅜" rib metal lath wire tied 5" o.c. to open web steel joists 24" o.c. supporting ⅜" rib metal lath and 2½" concrete slab.	 Approx. Ceiling Weight: 5 psf Fire Test: BMS 92/43, 10-7-42

FLOOR-CEILING ASSEMBLIES, STEEL FRAME, WOOD FLOOR

Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA
1 HR	45 to 49	FC 4500 (t)	**Construction Type: Steel Channel Joists, Plywood Floor, Gypsum Wallboard Ceiling** Double layer ½" type X gypsum wallboard applied at right angles to joists. Base layer attached with 1" type S-12 drywall screws 8" o.c. at butt joints over joists and 12" o.c. in the field. Face layer attached with 1½" long type G drywall screws 8" o.c. at butt joints between joists and with 1⅝" type S-12 drywall screws 12" o.c. in the field along joists. Face and base layer edge joints offset. Channel shaped 7" min depth, no. 18 min ga galv steel joists spaced 24" o.c., with 2" x 2" (nom) wood bridging. Flooring: ⅝" T&G edge plywood applied at right angles to joists with 1⅝" no. 6-20 S-12 point screws 6" o.c. around floor perimeter and at plywood end joints and 10" o.c. in field. Refer to gypsum board mfr for UL listed alternate sub and finish flooring systems.	 Approx. Ceiling Weight: 2½ psf Fire Test: UL R1319-133 Design L524, 7-16-75

SOUND INSULATION CONSTRUCTION

"Normal" Construction . . .
Arrows show flanking paths

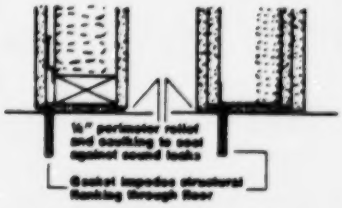


Elevation
Under and Over Partitions

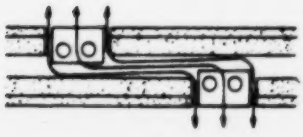
"Select" Construction . . .
Caulking of relief detail at perimeter of partition and around cut-outs to prevent sound leakage

Elevation

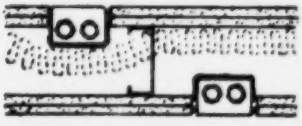
"Pre-design" Construction . . .
Simulating laboratory conditions



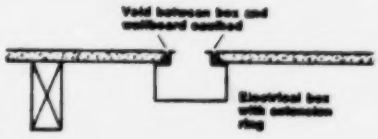
Elevation
Typical Floor-Ceiling or Roof Detail



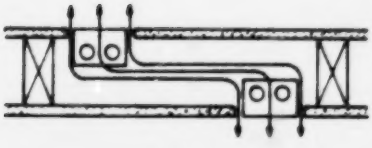
Plan
Through partitions-openings, outlet boxes



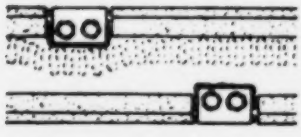
Plan
Indicating caulking of openings through partitions



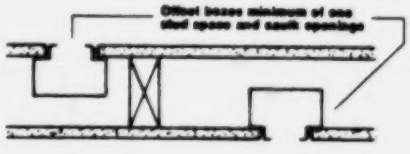
Plan
Outlet Box Detail



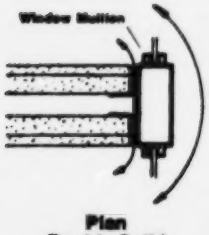
Plan
Through partitions-openings, outlet boxes



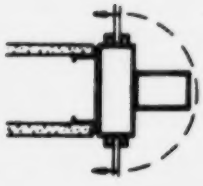
Plan
Indicating caulking of openings through partitions



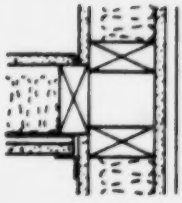
Plan
Outlet Box Details



Plan
Double Solid
Around-flanking partition ends

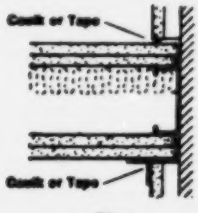


Plan
Typical partition-mullion intersection

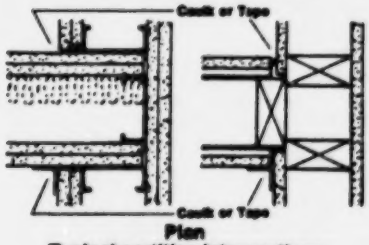


Plan
Intersection with exterior wall

Plan
Metal Stud
Around-flanking partition ends



Plan
Intersection with interior wall



Plan
Typical partition intersections

No. 2226

J. R. Sasaki

THERMAL PERFORMANCE OF EXTERIOR STEEL-STUD FRAME WALLS

Steel studs have been used quite successfully in the construction of interior partitions and are now being offered as an alternative to wood studs in exterior frame wall construction. In addition to its structural performance, the major consideration in the acceptance of an exterior steel frame wall for use in cold-weather regions is its thermal performance. As it was questionable whether existing calculation methods could predict the thermal performance of this type of wall, a laboratory investigation was undertaken to define the performance of steel frame walls and to determine the effect of some of the design features on their thermal performance. The results of the investigation were also used to check whether the calculation method outlined in ASHRAE HANDBOOK OF FUNDAMENTALS of the American Society of Heating, Refrigerating and Air-Conditioning Engineers[1] was adequate for evaluating walls that have high-conductance framing members bridging a layer of air-permeable insulation, and that experience convective heat exchange between the framing members and the air in the insulated stud space.

The cold-weather performance of an exterior wall is expressed by its over-all thermal resistance and inside surface-temperature characteristic.[2,3,4] The surface temperature characteristic determines the condensation potential and the dust-marking potential of the wall.

Objectionable condensation occurs on the inside surface of a wall whenever the surface temperature drops below the dew point temperature of the adjacent air; the minimum inside surface temperature (t_{min}) is, therefore, the upper limit for dew point temperature if condensation is to be avoided.

Differential dust marking is caused by sharp surface temperature gradients and by a large temperature difference between the surface and adjacent air.[5] The rate of dust deposition depends on the temperature difference between surface and air; dust patterns become more noticeable as surface temperature gradients increase. The dust-marking potential of frame walls can, therefore, be represented by the inside surface temperature over the stud (t_{stud}), the horizontal surface temperature gradient caused by the stud (Δt_h), and the surface temperature depression caused by the fasteners holding the interior wall panel to the studs (Δt_{screw}).

The minimum acceptable standards of heat-transmission performance and condensation performance of a wall can be specified without any difficulty. Unfortunately, the minimum standard of dust-marking performance cannot be specified as easily because dust marking depends not only on the surface temperature gradients but also on the severity and duration of the cold weather experienced, the cleanliness of the inside air, and the frequency of cleaning and redecoration. For example, exterior walls of conference rooms and living rooms, where tobacco smoke concentration is high, should have a higher performance rating than walls intended for classrooms or bedrooms, which have cleaner air. There is at present no quantitative information correlating the incidence of dust marking with wall surface temperature performance and the foregoing factors. In the absence of such information, the dust-marking performance of steel frame walls can only be judged by comparison with the performance of wood frame walls, which have proved to be reasonably acceptable in practice.

GENERALITIES ON FRAME WALL PERFORMANCE

Frame walls are characterized by an air space formed by the studs, inside wallboard and outside sheathing board. The air space may be partially or fully insulated, or may not be insulated at all. The frame walls discussed in this paper are either partially or completely filled with a blanket of air-permeable glass fiber insulation. The thermal performance of such walls is controlled by the studs which thermally bridge the insulation layer;[6] the thermal resistance of the insulation and wallboards; the convective air flow through the insulation;[7] and the convective heat exchange between the studs and the air in the stud space.

Studs that bridge the insulation layer reduce the over-all resistance of a wall and create large surface temperature differences on the inside wall surface. The bridging effect of wood studs is less than that of steel studs because of the lower conductivity of wood. The bridging effect of steel studs can be reduced by introducing a high-resistance element (thermal break) between the stud and wallboards, increasing the heat-flow path length between the cold and

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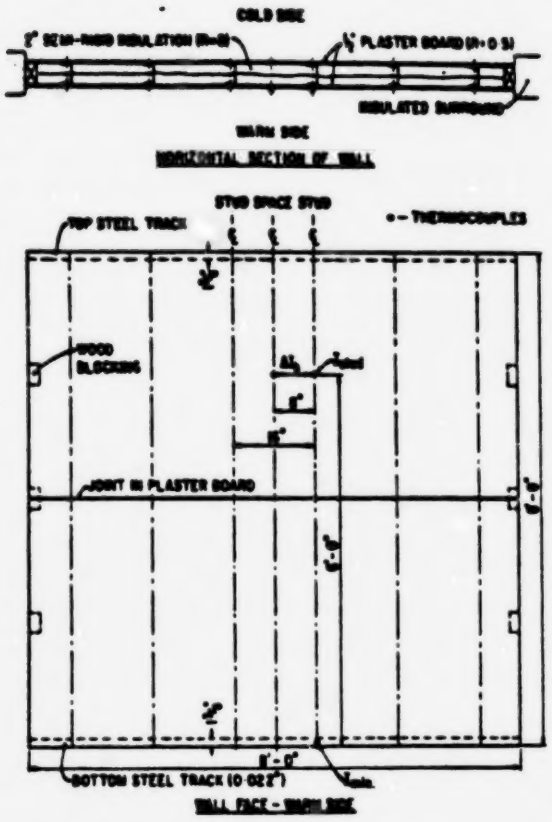

Fig. 1. Steel-stud wall configuration

warm faces of the stud, and reducing the cross-sectional area of the stud web.

The thermal resistance of the stud-space insulation and the inner and outer wallboards have a large effect on the thermal performance of frame walls, since these elements are the greatest contributors to the over-all resistance of a wall. Maximum resistance is achieved when the stud space is completely filled with insulation. Complete filling may, however, exaggerate the surface temperature depression caused by the studs and thereby increase the inside surface temperature gradients. Low conductivity wallboards on the inside and outside will increase the over-all resistance and also reduce the inside surface temperature gradients.

When the stud space in a frame wall is only partially filled with insulation, the location of the insulation layer relative to the inner and outer wallboards affects the surface temperature performance. Inside surface temperature gradients are smallest when the insulation is against the outer sheathing, since this location exposes part of the stud web to convective heat exchange with warm air in the stud space.

Convective air flow through and around the insulation layer is another important factor that can degrade the thermal performance of a wall when the stud space is only partially filled. This effect can be minimized by placing the insulation tightly against the inner or outer wallboard.

LABORATORY INVESTIGATION

Five steel-stud frame walls were constructed as shown in Fig. 1; stud details are shown in Fig. 2. Plaster facing boards were attached to the studs by steel screws. A 2-in. by 4-in. wood-stud frame wall having the same configuration was also constructed. The effect of the exterior finish was neglected in the walls investigated.

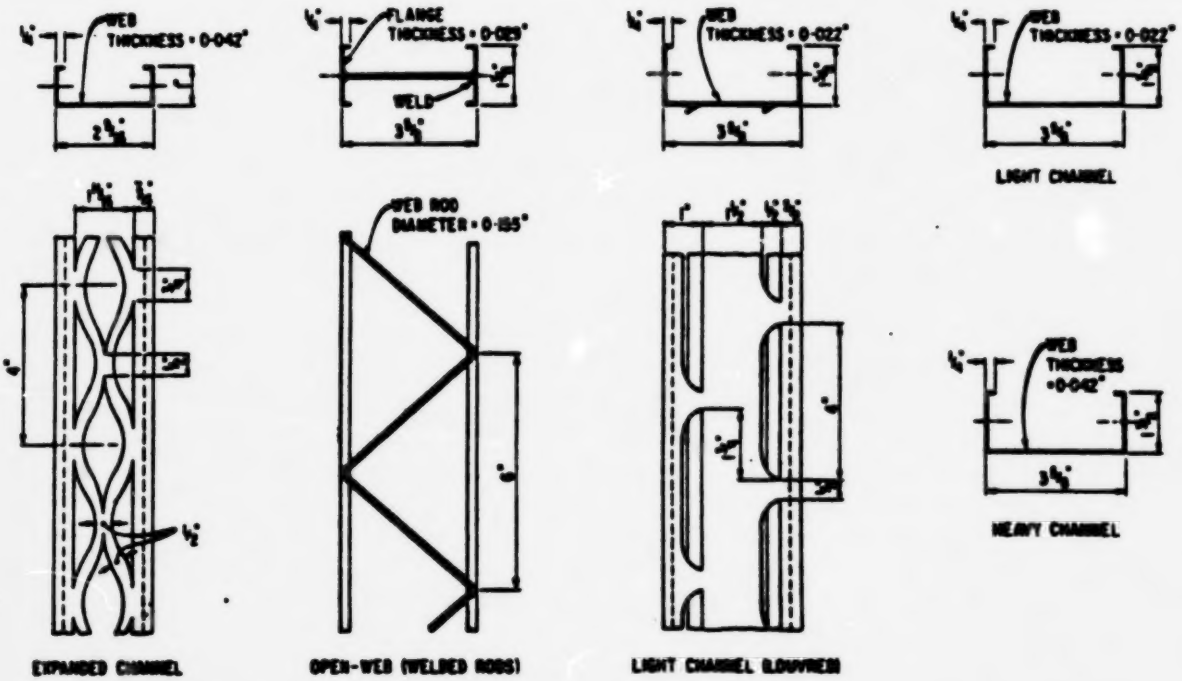

Fig. 2. Details of steel studs

TABLE I – Thermal Performance of Wood and Steel Frame Walls*

		Insulation Adjacent to Cold-Side Board					Insulation Adjacent to Warm-Side Board				
		R_o	I_{stud}	ΔI_h	ΔI_{screw}	I_{min}	R_o	I_{stud}	ΔI_h	ΔI_{screw}	I_{min}
(A)	**FRAME WALL PERFORMANCE (2-in. insulation, $R_i \approx 8$)**										
	Wood studs	10.5	93.5	0.2	1.8	90.3	10.5	91	4.1	3	87.8
	Steel studs – Open-web, expanded channel	8.7	89	6.2	3.9	75	–	–	–	–	–
	– Open-web, welded rods	8.3	90	3.8	–	76.5	8.3	86.5	8.1	–	73.3
	– Light channel, louvred	7.9	89.5	3.7	–	75.5	7.9	83.3	11.1	–	68.3
	– Light channel	7.1	84	10	6	75.5	7.3	76.5	18.3	–	72
	– Heavy channel	6.6	80	13.5	7.6	75.5	6.8	71	23.3	–	70
(B)	**EFFECT OF INCREASING AIR SPACE RESISTANCE**										
	Light-channel studs – With 2-in. insulation	7.1	84	10	6	75.5					
	– With 3-in. insulation ($\Delta R \approx 4$)	8.3	78.3	16.3	–	77.3					
(C)	**EFFECT OF INCREASING FACING RESISTANCE (With ½-in. fiberboard, $R_f \approx 1.3$)**										
	Expanded channel – plasterboard on both faces of wall	8.7	89	6.2	3.9	75					
	– ½-in. fiberboard in place of cold-side plasterboard ($\Delta R = 0.8$)	9.6	90	5	3.7	77					
	Light channel – plasterboard on both faces of wall	7.1	84	10	6	75.5					
	– ½-in. fiberboard added on cold-side ($\Delta R = 1.3$)	8.1	87.2	6.7	–	81					
	Heavy channel – plasterboard on both faces of wall	6.6	80	13.5	7.6	75.5					
	– ½-in. fiberboard in place of cold-side plasterboard ($\Delta R = 0.8$)	7.6	85.5	8.9	8.8	80.5					
	– 1-in. fiberboard in place of cold-side plasterboard ($\Delta R = 2.1$)	9.3	88.5	7	4.8	84.5					

*Warm surface conductance
≈ 1.4 Btu/(hr) (sq ft) (F)

Cold surface conductance
≈ 4.5 Btu/(hr) (sq ft) (F)

R = thermal resistance

$$= \frac{1}{\text{conductance}} \text{ or } \frac{1}{U} \text{ (hr) (sq ft) (F)/Btu.}$$

I = temperature index

$$= \frac{t - t_c}{t_w - t_c} \times 100$$

The walls were evaluated in the DBR/NRC wall-panel testing unit[8] with nominal air temperatures on the warm and cold sides of 70 F and - 20 F, respectively. The surface conductance values at the warm and cold faces of the wall were approximately 1.4 and 4.5 Btu/(hr) (sq ft) (F), respectively.

The inside surface temperature over the stud centerline (t_{stud}) and the horizontal surface-temperature difference between stud centerline and stud-space centerline (Δt_h) were measured approximately 6 ft above the wall base. The minimum inside surface temperature (t_{min}) was measured at the intersection of the stud and the bottom track but away from any attachment screws. The additional surface temperature depression caused by the steel attachment screws (Δt_{screw}) was measured for some of the walls.

The thermal performance of the walls was determined with 2-in. semi-rigid insulation against the cold-side sheathing board, and again with the insulation against the interior finish. The performance of the light-channel wall was also determined with 3 in. of the same insulation, which effectively filled the space between the studs. Additional tests were performed on some of the walls using cold-side sheathing boards having a higher thermal resistance than the standard plasterboard.

The over-all thermal resistance, R_o, and the surface temperature characteristic of the walls are listed in Table I. The inside surface temperature characteristics are expressed in terms of a temperature index, I, defined as:

$$I = \frac{t - t_c}{t_w - t_c} \times 100,$$

where t_w and t_c are the warm and cold side air temperatures, respectively. Thus, the terms, I_{stud}, ΔI_h, ΔI_{screw} and I_{min} are the non-dimensional equivalents of the inside surface temperatures, t_{stud}, Δt_h, Δt_{screw} and t_{min}, respectively.

Surface temperatures and temperature differences for particular warm- and cold-air conditions can be calculated using the tabulated values of temperature indices and the foregoing equation, as shown in the following example.

> The values of I_{stud} and ΔI_h for the light-channel steel wall with insulation to cold side, are listed as 84 and 10, respectively. For an inside air temperature of 70 F and an outside air temperature of 10 F, the values of t_{stud} and Δt_h would be:
>
> $$t_{stud(10\ F)} = I_{stud} \times \frac{(70 - 10)}{100} + 10 = 60.4\ F$$
>
> $$\Delta t_{h(10\ F)} = \Delta I_h \times \frac{(70 - 10)}{100} = 6\ F\ deg.$$

Wood Frame Wall Performance

The surface temperature performance of the wood frame wall was better when the insulation was to the cold side rather than the warm side. The latter configuration, however, is the usual method of installation with paperbacked insulation. The inside surface temperature characteristic of this wall is shown in Fig. 3. The overall resistance of the wall was 10.5 (hr) (sq ft) (F)/Btu. The inside surface temperature index over the stud (I_{stud}) was 91; the horizontal

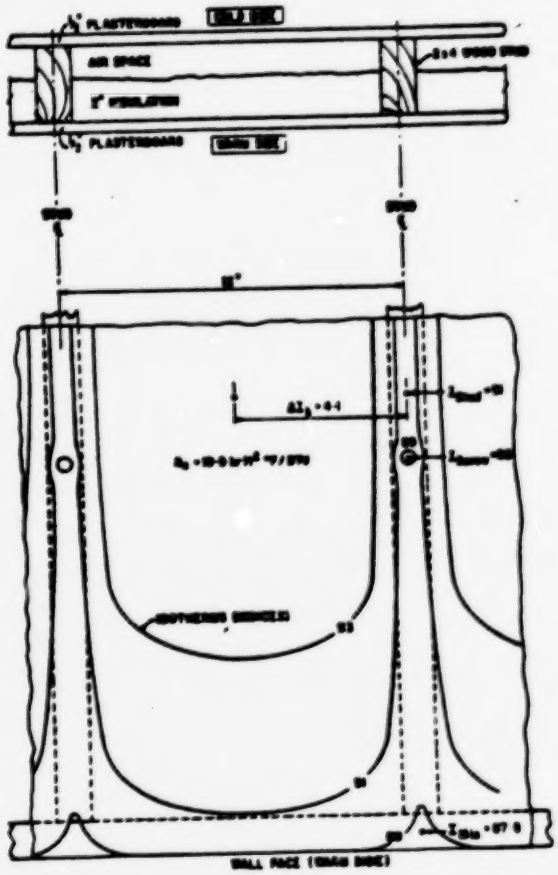

Fig. 3. Inside surface temperature characteristic (indices) – wood frame wall

surface temperature index difference (ΔI_h) caused by the stud was 4.1; the surface temperature index over the attachment screw (I_{screw}) was 88 ($I_{stud} - \Delta I_{screw}$); and the minimum inside surface temperature index (I_{min}) was 87.8. This is the thermal performance standard against which the steel frame walls were compared.

Steel Frame Wall Performance

The walls with the open-web studs had significantly higher resistance values than the solid-stud walls; and the inside surface-temperature characteristics of the walls with the open-web studs were closer to the characteristics of the wood wall. This is apparent in Fig. 4 where the horizontal surface-temperature profiles of the open-web (welded rod) stud wall and the heavy-channel stud wall are compared with that of the wood wall.

The steel screws used to fasten the inside wallboard to the studs caused a local depression in the inside wall surface temperature. This temperature depression, ΔI_{screw}, was linearly dependent on ΔI_h, as shown in Fig. 5. The screw temperature difference must be added to ΔI_h to indicate the maximum horizontal temperature difference that would occur on the inside surface of a wall, and subtracted from I_{min} to indicate the lowest wall surface temperature.

The over-all resistance of the steel walls was relatively unaffected by the location of the insulation in the stud

Table II – Calculated Wall Thermal Performance*

WALL CONFIGURATION	R_o		I_{stud}		ΔI_h	
	Measured	Calculated	Measured	Calculated	Measured	Calculated
(1) Wood frame wall						
2-in. insulation adjacent to cold side	10.5	10.2	93.5	89.3	0.2	4.4
2-in. insulation adjacent to warm side	10.5	10.5	91	89.5	4.1	4.3
(2) Welded-rod steel stud						
2-in. insulation adjacent to cold side	8.3	9.5	80	85.2	3.8	8.6
(3) Light-channel steel stud						
2-in. insulation adjacent to cold side	7.1	7.95	84	74.8	10	19
2-in. insulation adjacent to warm side	7.3	8.05	76.5	75	18.3	18.9
3-in. insulation adjacent to cold side	8.3	9.6	78.3	76.5	16.3	20
(4) Heavy-channel steel stud						
2-in. insulation adjacent to cold side	6.6	7.35	80	70.2	13.6	23.6
2-in. insulation adjacent to warm side	6.75	7.45	71	70.5	23.3	23.4
2-in. insulation adjacent to cold side; 1-in. fiberboard in place of cold side plasterboard.	9.35	9.7	88.5	84.5	7	10

*Warm surface conductance = 1.4 Btu/(hr) (sq ft) (F)
Cold surface conductance = 4.5 Btu/(hr) (sq ft) (F)

R = thermal resistance = $\frac{1}{\text{conductance}}$ or $\frac{1}{U}$; (hr) (sq ft) (F)/Btu

I = temperature index = $\frac{t - t_c}{t_w - t_c} \times 100$

space, but the surface temperature differences were greater and the minimum wall temperature lower when the insulation was towards the inside rather than the outside. For example, ΔI_h for the heavy-channel wall increased by 9.8 and I_{min} dropped by 5.5 when the insulation was moved from the cold side to the warm side.

The thermal resistance of the steel frame walls was improved by increasing the thickness of insulation in the stud space and by increasing the thermal resistance on the inner and outer faces of the wall. Increasing the thickness of the stud-space insulation in the light-channel wall from 2 in. to 3 in. increased the over-all resistance of the wall by 1.2 units. This increase in resistance was accompanied, however, by an increase in ΔI_h of 6.3.

A better method for increasing the over-all wall resistance was to add high-resistance material on the face of the wall. Replacing the plasterboard on the cold side of the heavy-channel wall with 1-in. fiberboard increased the over-all resistance by 2.7 units and reduced ΔI_h by 6.5. The surface temperature profile of the heavy-channel wall with this high-resistance sheathing is shown in Fig. 4.

Although the minimum surface temperatures measured on the steel walls were considerably lower than those measured on the wood walls, none of the walls appeared to have a minimum value so low as to cause inside surface condensation problems under normal conditions of use.

For example, the heavy channel wall with R7 insulation to the warm side had a minimum index of, $I_{min} = 70$. Fig. 5 indicated a further screw index depression of approximately $\Delta I_{screw} = 12$ for this wall. A screw located at the intersection of the bottom track and a stud would, therefore, have a temperature index of 58, which is lower than that of any other wall. For outdoor and indoor air temperature of 0 F and 72 F, respectively, the minimum screw temperature would be 42 F; condensation would not occur on the screw until the inside relative humidity exceeded approximately 35%.

Calculated Thermal Performance

As a primary purpose of the study was to determine whether the thermal performance of frame walls could be evaluated without testing, the over-all resistances and inside surface temperatures of a number of the simpler frame wall configurations were calculated using the "zone" method described in the 1967 ASHRAE HANDBOOK OF FUNDAMENTALS (Chapter 26, page 421). The calculated and measured values are compared in Table II. The calculated resistance values were just slightly lower than the measured

values for the wood frame walls, but were 4 to 15% higher than the measured values for the steel walls. This is not too surprising considering the zone method does not account for convective heat transfer in the stud space or convective air exchange through the insulation. The calculated values of Δt_h were close to the measured values for only those walls with insulation towards the warm side; the agreement was poor for all the other walls.

SUMMARY

High-resistance steel studs used in frame wall construction can provide thermal performance comparable to that of wood frame walls. Lower-resistance steel studs can provide comparable performance if some of the following suggestions are incorporated in the wall design:

(1) Use stud-space insulation having a thickness less than the depth of the stud, and place it against the cold-side sheathing board.

(2) Use material with a high thermal resistance for the cold-side sheathing and the interior finish.

(3) Place a high-resistance spacer between the stud and the outer and/or inner wallboards, or between the exterior wallboard and exterior cladding material.

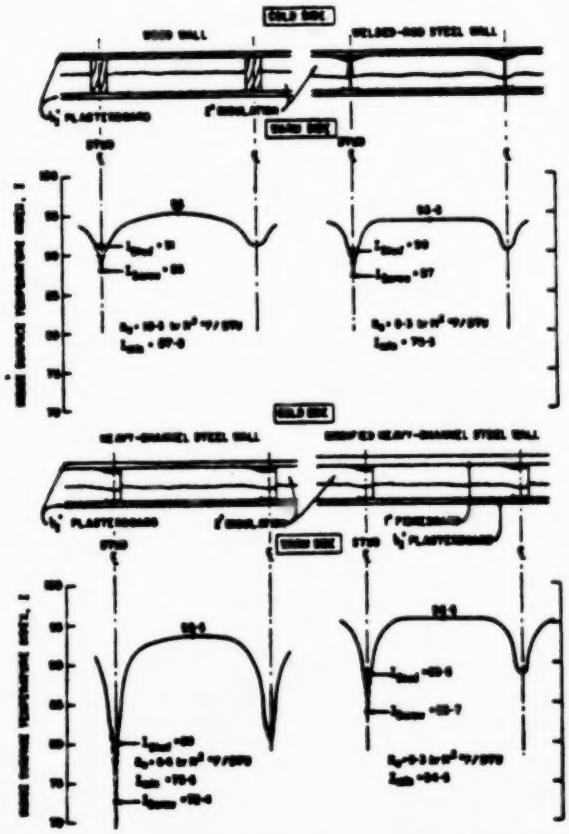

Fig. 4. Horizontal temperature profiles on inside surface of four walls (indices)

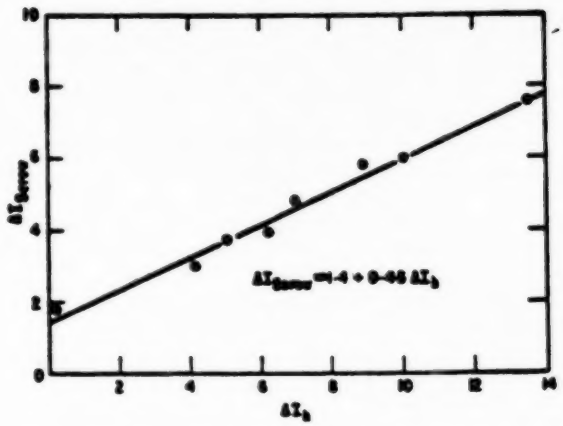

Fig. 5. Dependence of screw temperature depression on stud temperature difference

The need for care in placing stud-space insulation tightly against a wallboard and against the studs must be emphasized. Lips on the flanges of the steel studs tended to create air voids on both sides of the insulation near the studs that permitted convective air flow through the insulation. Improperly located thermal separators between the studs and wallboards would also create similar voids and air circulation. Thus, the possible reduction in the thermal effectiveness of the insulation must be recognized when friction-fit insulation without paper backing is used in steel frame walls.

The current study indicates that the ASHRAE "zone" method of calculation is capable of estimating the over-all resistance of steel frame walls reasonably well, but is incapable of estimating the inside surface temperature performance with any reliability.

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5. R. A. Nielsen, Dirt Patterns on Walls, ASH&VE TRANSACTIONS, Vol. 46, 1940, p. 247.
6. W. P. Brown and A. G. Wilson, Thermal Bridges in Buildings, Canadian Building Digest No. 44, 1963, Division of Building Research, National Research Council of Canada.
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CHARLES F. GILBO (Armstrong Cork Co., Lancaster, Pa.): We verified your studies very closely in a mobile home study. In the mobile home industry some manufacturers are contemplating going to metal frames and we have been interested in the thermal properties of these units. The variations that you have noticed in the thermal pattern at the stud locations have to do primarily with internal convection within the walls. If you take ASHRAE GUIDE AND DATA BOOK data and consider it only for those cases that do not have internal convection, the computed check is very good, but if you do have a wall construction that has a high internal convection factor, then the check is very poor.

MR. SASAKI: I agree. The zone method being only a convective arithmetic method does not account for convective heat exchange within the wall spaces.

MR. GILBO: Your Fig. 3 was most interesting because that really did show the effect of the convection within the stud space. The differences in surface temperature were coming primarily from the segregation and lamination of the air within the space.

ALEX MERRILL (Peoples Gas Co., Chicago, Ill.): You didn't make any comment on dust marking. I wondered if you concluded any.

MR. SASAKI: As I indicated in my opening remarks, there are many factors that affect dust marking. We only looked at the surface temperature aspect of the problem. Factors such as the cleanliness of the room air, the duration and severity of the cold weather conditions, or the frequency of cleaning of the walls, were not studied. I should report that, subsequent to the laboratory study, I examined a number of high-rise apartment buildings that had steel-stud walls. Some of these buildings had been up for three or four years, but I didn't notice, with the exception of one building, any dust marking associated with the steel studs that was severe enough to be noticeable. In one suite of one apartment building I did see dust marking over the studs, but not enough to be objectionable. A more common problem was dust marking over the baseboard convectors.

JOHN I. YELLOTT (Yellott Solar Energy Labs, Phoenix, Ariz.): Why does the dust go to the cold instead of the warm parts of the wall?

MR. SASAKI: According to Nielson, dust marking is a thermal phenomenon, unrelated to humidity conditions or to air permeability of the wall. The molecular activity of the air propels dust particles against the wall in the direction of the air temperature gradient. Dust deposition is greatest where the temperature difference between the air and surface is greatest; that is, at the coldest surfaces.

MR. YELLOTT: I have listened with the greatest of interest to these two previous papers and I would like to commend the authors on the truly elegant approach to two very difficult problems. I think that the dust marking effect had the name Blacktin Effect. Some 30 years ago, when I was at the Institute of Gas Technology in Chicago, we were trying to find ways to improve dust collection and I came upon that name. I think I can find the reference for you. It was the Royal Society of London; an obscure paper by an obscure physicist. Now it is nothing like as obscure because it has become a real problem, as we have just heard.

METAL LATH/STEEL FRAMING ASSOCIATION
221 North LaSalle Street
Chicago, Illinois 60601
Phone 312/346-1862

Light Gage Steel Framing Specifications

DIVISION 5

0540—**Light Gage Framing**

These specifications are intended as a guide in the preparation of specifications for a particular project. They must, of course, be modified to suit the conditions of use, with particular attention given to the deletion of inapplicable provisions.

PART 1. GENERAL

1.01 **INTENT**

The intent of this recommended Specification is to establish general guidelines for the design, fabrication and erection of the Light Gage Cold-Formed Structural Steel System. Specific criteria and certain restrictions are also included herein.

1.02 **WORK SPECIFIED ELSEWHERE**

The following related work is not covered in this section, but is specified under other sections of this Specification.

A. Structural Steel (i.e. structural beams and columns)
B. Interior Non-Load Bearing Light Gage Steel Stud Walls, Except Shear Walls

1.03 **APPLICABLE DOCUMENTS**

The following documents of the issue in effect on date of material procurement, referred to thereafter by basic designation only, form a part of this specification to the extent indicated by reference thereto.

A. Specification for the Design of Cold-Formed Steel Structural Members, American Iron and Steel Institute.
B. Specifications for Metal Lathing and Furring, Metal Lath/Steel Framing Association.
C. ASTM A-446—Specification for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process, Physical (Structural) Quality.
D. ASTM A-570—Specification for Hot-Rolled Carbon Steel Sheets and Strip, Structural Quality.
E. ASTM A-611—Specification for Steel, Cold-Rolled Sheet, Carbon, Structural.

PART 2. MATERIALS

2.01.01 Design, analysis and computation of section properties shall be in conformance with the Specification for the Design of Cold-Formed Steel Structural Members of the American Iron and Steel Institute.

2.01.02 Technical tabulations of section properties and load capacities shall indicate dimensions, steel characteristics and allowable stresses upon which computations are based.

2.02.01 Composite design systems shall incorporate a cementitious membrane facing attached to the studs through a series of shear connectors. Composite design shall not increase allowable axial loads nor allowable bending strength. Composite design shall improve deflection characteristics only.

2.02.02 Metal lath for cementitious membrane facings shall be of the type and weight for the spacing of supports in accordance with the Specifications for Metal Lathing and Furring.

2.03 All steel members shall be galvanized or primed with rust-inhibiting paint.

2.04 All 16 gage and heavier painted structural members shall be formed from steel that corresponds to the requirements of ASTM A-570, with a minimum yield of 50 ksi.

2.05 All 16 gage and heavier galvanized structural members shall be formed from steel that corresponds to the requirements of ASTM A-446, Grade D (minimum yield of 50 ksi).

2.06 All 18 gage and lighter painted structural members shall be formed from steel that corresponds to the requirements of ASTM A-611, Grade C (minimum yield of 33 ksi).

2.07 All 18 gage and lighter galvanized structural members shall be formed from steel that corresponds to the requirements of ASTM A-446, Grade A (minimum yield of 33 ksi).

PART 3. FABRICATION AND ERECTION

3.01 Prior to the commencement of fabrication of framing, contractor shall submit fabrication and erection drawings to architect and obtain his approval.

3.02 Provide stud walls at locations indicated on plans as "shear walls" for frame stability and lateral load resistance. Such stud walls shall be braced as indicated on plans and specifications. Additional studs shall be positioned to resist the vertical components as indicated on plans and specifications.

3.03 At corners of stud walls provide three studs minimum, located so as to provide surfaces for attachment of all interior and exterior facings.

3.04 Provide web stiffeners at reaction points where indicated by plans and specifications.

3.05 All framing components shall be cut squarely or at an angle to fit squarely against abutting members. Members shall be held firmly in position until properly fastened. Pre-fabricated panels shall be square. Wire tying of framing components in structural applications is not permitted.

3.06 Members comprising trusses shall be joined by welding.

3.07 Joists shall be sized and spaced as shown on drawings. Provide additional joists or "blocking" adjacent to exterior and interior walls, openings and elsewhere as necessary to provide support for ceiling construction as indicated by plans and specifications. Provide an additional joist under parallel partitions when the partition length exceeds one-half the joist span and around all floor and roof openings which interrupt one or more spanning members, unless otherwise noted.

3.08 Provide lateral bracing and bridging in wall, floor and roof systems to manufacturer's specifications or recommendations.

3.09 Track shall be securely anchored to floor and overhead structure as indicated by plans and specifications. Axially loaded studs shall be seated squarely in the track with the stud web and flange abutting the track web, and all studs shall be plumbed and aligned and securely attached to the flanges or webs of both upper and lower tracks.

3.10 Splices in axially loaded studs shall not be permitted.

F. MANUFACTURERS AND SUPPLIERS

1. Addresses
2. Product Literature

MANUFACTURERS/SUPPLIERS/INSTITUTES

Mr. Gerry Elliot
Westroc Industries Ltd.
2650 Lakeshore Highway W.
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Paul Benson, President
Benson Steel
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Woodbridge, Ontario
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Len Dury, Sales Rep.
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Mr. John Rice
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151 Bentworth Avenue
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Toronto Construction Assoc.
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Willowdale, Ont M2H 2W1

Randob Enterprises Ltd.
53 Pheasant Lane
Toronto, Ontario
M9A 1T5

Attn: Mr. Ernie Bobnar

Donn Canada Ltd.
735 Fourth Line
Oakville, Ontario
L6L 5B7

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American Iron and Steel Producers
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Washington D.C.
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Mr. Andrew Zireskie
Manager, Project Engineering
Defasco Inc.
P.O. Box 460
Hamilton, L8N 3J5

Mr. John Adam, Assistant Marketing Mgr.
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Canadian Sheet Steel Bldg. Institute
305-201 Consumers Road
Willowdale, Ontario M2J 4G8

Attn: Mr. D.L. Tarlton, P. Eng.
General Manager

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   Metal Lath/Steel Framing Association
   221 North LaSalle Street
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   Gypsum Association
   1603 Orrington Ave.
   Evanston, Illinois, 60201

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   Committee of Sheet Steel Producers
   American Iron & Steel Institute
   1000 16th Street, N.W.
   Washington, D.C. 20036

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   United States Gypsum
   General Offices
   101 South Wacker Drive
   Chicago, Illinois 60606

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Publication prepared by Subcommittee on fire Technology of the Committee on Construction Codes and Standards, 1981.

American Iron & Steel Institute
1000 16th Street N.W.
Washington , D.C. 20036

9. Inryco/Milcor
Steel Framing Systems, Catalogue 37-1

Inryco - An inland Steel Company

10. Speed Steel - Framing System
Catalogue 1174 SF, Jan, 1975

Keene Corporation, Metal Products Division
Penn Metal Operation
P.O. Box 1468
Parkersburg, West Virginia 26101

11. Super-C Steel Studs Product Information
United States Steel.

12. Wheeling Steel Framing
Wheeling Corrugating Company, A division of Wheeling-Pittsburgh Steel Corp.
Wheeling, West Virginia, 26003

13. Westland Metals, Steel Framing Systems
1700 No. 6 Road, Richmond, B.C. V6V 1W3

POOR

QUALITY

ORIGINAL